# ENERGIJA

JOURNAL OF ENERGY

05/07

# ENERGIJA

**IZDAVAČ**
Hrvatska elektroprivreda d.d., Zagreb

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Ulica grada Vukovara 37, 10000 Zagreb, Hrvatska
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2360000-1400129978

Godišnja pretplata za inozemstvo iznosi USD 95.
Devizni račun:
Zagrebačka banka broj: 2000006299

Grafičko uređenje omota – mr. sc. Kažimir Vrankić, Zagreb
Grafičko uređivanje – Bestias dizajn d.o.o., Zagreb
Tisak – Intergrafika d.o.o, Zagreb

Naklada – 1 500 primjeraka
Zagreb, 2007

Godište 56(2007)
Broj 5., str. 521–636

Oglasi su veličine jedne stranice. Cijena oglasa je 3 000 kn bez PDV (22%).

# ENERGIJA

**PUBLISHED BY**
Hrvatska elektroprivreda d.d., Zagreb

**PUBLISHER'S REPRESENTATIVE**
Ivan Mravak, MSc

**CO-PUBLISHED BY**
Univesity of Zagreb, Fakulty of Electrical Engineering and Computing
Ministry of Economy, Labour and Entrepreneurship

**SUPPORTED BY**
Ministry of Science, Education and Sport

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Appears 6 times a year.
Annual subscription fee excl. VAT (22 %):
– for individual subscribers HRK 250
– for companies HRK 400
– for students HRK 60
Number of gyro account with Zagrebačka Banka:
2360000-1400129978

Annual subscription fee for the overseas: USD 95.
Number of foreign currency account with Zagrebačka Banka:
2000006299

Cover design – Kažimir Vrankić, MSc, Zagreb
Graphic layout – Bestias Dizajn d.o.o., Zagreb
Printed by – Intergrafika d.o.o., Zagreb

Circulation – 1,500 copies
Zagreb, 2007

Volume 56(2007)
No 5., pp. 521–636

Ads are the size of page. The price of an ad is HRK 3 000 excl. VAT (22%).

## SADRŽAJ



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Časopis je ubilježen u Ministarstvu znanosti, obrazovanja i sporta pod brojem 161 od 12.11.1992.

Časopis je indeksiran u sekundarnom bibliografskom izvoru INSPEC – The Institution of Electrical Engineering, England.

The magazine is registered with the Ministry of Science, Education and Sport under No. 161 since 12.11.1992.

The magazine is indexed with the secondary reference source of INSPEC – The Institution of Electrical Engineering, England.

# UREĐIVAČKA POLITIKA

Časopis Energija znanstveni je i stručni časopis s dugom tradicijom više od 50 godina. Pokriva područje elektroprivredne djelatnosti i energetike. Časopis Energija objavljuje izvorne znanstvene i stručne članke širokoga područja interesa, od specifičnih tehničkih problema do globalnih analiza procesa u području energetike.

U vrlo širokom spektru tema vezanih za funkcioniranje elektroprivredne djelatnosti i općenito energetike u tržišnim uvjetima i općoj globalizaciji, časopis ima poseban interes za specifične okolnosti ostvarivanja tih procesa u Hrvatskoj i njezinu regionalnom okruženju. Funkcioniranje i razvoj elektroenergetskih sustava u središnjoj i jugoistočnoj Europi, a posljedično i u Hrvatskoj, opterećeno je mnogobrojnim tehničko-tehnološkim, ekonomskim, pravnim i organizacijskim problemima. Namjera je časopisa da postane znanstvena i stručna tribina na kojoj će se kritički i konstruktivno elaborirati navedena problematika i ponuditi rješenja.

Časopis je posebno zainteresiran za sljedeću tematiku: opća energetika, tehnologije za proizvodnju električne energije, obnovljivi izvori i zaštita okoliša; korištenje i razvoj energetske opreme i sustava; funkcioniranje elektroenergetskoga sustava u tržišnim uvjetima poslovanja; izgradnja elektroenergetskih objekata i postrojenja; informacijski sustavi i telekomunikacije; restrukturiranje i privatizacija, reinženjering poslovnih procesa; trgovanje i opskrba električnom energijom, odnosi s kupcima; upravljanje znanjem i obrazovanje; europska i regionalna regulativa, inicijative i suradnja.

Stranice časopisa podjednako su otvorene iskusnim i mladim autorima, te autorima iz Hrvatske i inozemstva. Takva zastupljenost autora osigurava znanje i mudrost, inventivnost i hrabrost, te pluralizam ideja koje će čitatelji časopisa, vjerujemo, cijeniti i znati dobro iskoristiti u svojem profesionalnom radu.

# EDITORIAL POLICY

The journal Energija is a scientific and professional journal with more than a 50-year tradition. Covering the areas of the electricity industry and energy sector, the journal Energija publishes original scientific and professional articles with a wide area of interests, from specific technical problems to global analyses of processes in the energy sector.

Among the very broad range of topics relating to the functioning of the electricity industry and the energy sector in general in a competitive and globalizing environment, the Journal has special interest in the specific circumstances in which these processes unfold in Croatia and the region. The functioning and development of electricity systems in Central and South Eastern Europe, consequently in Croatia too, is burdened with numerous engineering, economic, legal and organizational problems. The intention of the Journal is to become a scientific and professional forum where these problems will be critically and constructively elaborated and where solutions will be offered.

The Journal is especially interested in the following topics: energy sector in general, electricity production technologies, renewable sources and environmental protection; use and development of energy equipment and systems; functioning of the electricity system in competitive market conditions; construction of electric power facilities and plants; information systems and telecommunications; restructuring and privatization, re-engineering of business processes; electricity trade and supply, customer relations; knowledge management and training; European and regional legislation, initiatives and cooperation.

The pages of the Journal are equally open to experienced and young authors, from Croatia and abroad. Such representation of authors provides knowledge and wisdom, inventiveness and courage as well as pluralism of ideas which we believe the readers of the Journal will appreciate and know how to put to good use in their professional work.

# UVOD
# INTRODUCTION

**Dragi čitatelji,**
u rukama Vam je novi broj časopisa Energija koji, kao i do sada, donosi niz aktualnosti iz područja tržišta električne energije te pojedinih specijalističkih područja u elektrotehnici. U svijetu, ali i u Hrvatskoj, dominiraju teme vezane uz razvoj i izgradnju energetskih infrastrukturnih sustava, bilo da se radi o plinskom ili elektroenergetskom sustavu. Stručna javnost osim o ovim važnim aspektima energetskih i elektroenergetskih sustava razmatra i pitanja regulacije energetskih djelatnosti, odnosno regulatorne politike koja treba omogućiti uspostavu tržišta umreženih energenata; električne energije i prirodnog plina.

U ovom broju časopisa Energija, objavljujemo članke koji su na neposredan ili posredan način vezani uz regulaciju energetskih djelatnosti, a isto tako i članke iz pojedinih specijalističkih područja elektrotehnike:

- Uloga regulatornog tijela u donošenju tarifnih sustava – okrugli stol – prikaz i zaključci
- Regulatorna politika i njen utjecaj na planove razvoja i izgradnje energetskih subjekata koji obavljaju regulirane djelatnosti
- Numerički proračun niskofrekvencijskih elektromagnetskih prijelaznih pojava u energetskim transformatorima
- Dijagnostički pregled raspada elektroenergetskog sustava na otoku rodosu
- Baza podataka relejne zaštite.

U prvom članku su prikazani zaključci s Okruglog stola Hrvatskog ogranka CIGRE Studijskog odora C5 – Tržište električnom energijom i regulacija. Naime, reforma elektroenergetskog sektora podrazumljeva i reformu tarifnog sustava koja bi se trebala provesti početkom sljedeće godine i u ovom članku dani su vrlo zanimljivi komentari zainteresiranih strana u hrvatskom elektroenergetskom sektoru, ali i relevantnih eksperata iz europskih regulatornih tijela i zemalja s višegodišnjim iskustvom u ekonomskoj regulaciji, bilo da se radi o dugogodišnjim članicama EU, ili zemljama koje su tek nedavno postale članice EU.

**Dear Readers,**
You are holding the most recent issue of the journal *Energija*, which continues to present news about the electricity markets and individual specialized fields in electrical engineering. In the international community as well as Croatia, there is major interest in the development and construction of energy infrastructure systems, both gas or electricity. The professional public is also concerned with questions regarding the regulation of energy activities and regulatory policies for the purpose of establishing markets for networked energy.

In this issue of the journal, we are presenting articles that are directly or indirectly connected with the regulation of energy activities and articles from individual specialized areas of electrical engineering:

- The Role of the Regulatory Agency in the Adoption of Tariff Systems: Round Table Discussion – Report and Conclusion
- Regulatory Policy and Its Impact on the Development and Construction Plans of Regulated Energy Entities
- The Numerical Calculation of Low Frequency Electromagnetic Transient Phenomena in Power Transformers
- Diagnostic Review of a Blackout in Rhodes
- Relay Protection Database

The first article presents conclusions from the Round Table Discussion on the Role of the Regulatory Agency in the Adoption of Tariff Systems organized by the Croatian National Committee of CIGRE – C5 – Electricity Markets and Regulation. Reform of the electricity sector also includes reform of the tariff system, which should be implemented early next year. This article provides valuable commentaries by interested parties in the Croatian electricity sector as well as relevant experts from the European regulatory bodies and countries with many years of experience in economic regulation, long-time members of the EU as well as countries that have recently become members.

U postupku davanja suglasnosti na visinu tarifnih stavki, Hrvatska energetska regulatorna agencija daje suglasnost na trogodišnje planove razvoja i izgradnje prijenosne, odnosno distribucijske mreže. Tako se u drugom članku daju komentari na različite aspekte regulatorne politike, koja u velikoj mjeri može utjecati na razvoj prijenosne i distribucijske mreže te na poslovanje subjekata koji obavljaju regulirane djelatnosti.

Model transformatora primjenjiv u niskofrekvencijskim elektromagnetskim prijelaznim pojavama s frekvencijama reda veličine približno 1 kHz, prikazan je u trećem članku. U radu se polazi od matematičkog i analitičkog modela, a zatim je zbog ograničenja analitičkog modela u analizu uveden numerički pristup rješavanja krutih diferencijalnih jednadžbi koje opisuju prijelaznu pojavu. Razvijeni algoritam može se uspješno koristiti u ostalim niskofrekvencijskim prijelaznim pojavama gdje je glavni predmet analize nelinearni karakter transformatora.

Članak skupine autora iz Grčke daje sažet prikaz i analizu raspada elektroenergetskog sustava otoka Rodosa. Opisani i dijagnosticirani raspad elektroenergetskog sustava vrlo je zanimljiv s obzirom da se radi o izoliranom sustavu u kojemu se sukcesivno događa nekoliko poremećaja različitih uzroka i posljedica.

Posljedni članak obrađuje temu baze podataka, u ovom slučaju podataka o relejnoj zaštiti. U dobro strukturiranom članku daje se model korištenja baze svih relevantnih podataka vezanih uz relejnu zaštitu i to na način da se koristi relativno lako dostupan komercijalni program. Posebna značajka ovog modela upravljanja bazom podataka je njegova jednostavnost, što znači da potrebna razina znanja o tehnikama baza podataka te načinu pretraživanja i čuvanja podataka ne mora biti visoka.

Članke u ovom broju časopisa Energija potpisuje dvanaest autora iz sveučilišne zajednice, ali i iz prakse, što je, vjerujem, rezultiralo i kvalitetnim člancima.

**Glavni urednik**
**mr. sc. Goran Slipac**

As part of the procedure for authorizing the amounts of tariff items, the Croatian Energy Regulatory Agency authorizes three-year development and construction plans for transmission and distribution networks. The second article provides commentaries on various aspects of the regulatory policy, which can have a considerable impact upon the development of the transmission and distribution networks, as well as the operations of the regulatory bodies.

In the third article, a transformer model is presented that is applicable to low frequency electromagnetic transient phenomena of up to 1 kHz.  The article first presents analytical and mathematical models. Due to the limitations of the analytical model, a numerical approach is introduced for the solution of the stiff differential equations that describe the transient phenomena.  The algorithm developed can be used successfully in other low frequency transient phenomena where the main subject of analysis is the nonlinear character of the transformer.

An article by a group of authors from Greece summarizes and analyzes a blackout that occurred in the electrical energy system on the island of Rhodes. The description and diagnosis of the system blackout is very interesting because it concerns an isolated system in which there were successive perturbations with various causes and consequences.

The last article concerns the topic of databases, in this case data on relay protection. This well-structured article presents a relay protection data model using the easily obtainable Microsoft Access Database Program. A particular characteristic of this model of database management is its simplicity, which means that the required level of user knowledge regarding database techniques, searches and data storage need not be high.

The articles in this issue of the journal *Energija* are signed by twelve authors from the university and energy bussines.

**Editor-in-Chief**
**Goran Slipac, MSc**

# ULOGA REGULATORNOG TIJELA U DONOŠENJU TARIFNIH SUSTAVA: OKRUGLI STOL – PRIKAZ I ZAKLJUČCI

# THE ROLE OF THE REGULATORY AGENCY IN THE ADOPTION OF TARIFF SYSTEMS: ROUND TABLE DISCUSSION – REPORT AND CONCLUSION

Dr. sc. Mićo Klepo, Hrvatska energetska regulatorna agencija, Koturaška cesta 51, 10000 Zagreb, Hrvatska

Krajem 2006. godine Hrvatska energetska regulatorna agencija donijela je metodologije za izračun tarifa za djelatnosti proizvodnje, prijenosa, distribucije i opskrbe električnom energijom, koje su do sada bile komponente jedinstvene tarife za integrirani sustav djelatnosti proizvodnje, prijenosa, distribucije i opskrbe električnom energijom. Sukladno zakonskoj obvezi razdvajanja navedenih djelatnosti, izraženih i kroz pristup spomenutim metodologijama tarifnih sustava, u tijeku su poslovi vezani uz izračun i donošenje tarifnih stavki za navedene energetske djelatnosti.
Primjenom spomenutih metodologija, odnosno donošenjem i stupanjem na snagu novih tarifnih stavki elektroenergetski sektor i elektroenergetsko gospodarstvo Republike Hrvatske ući će u probno regulatorno razdoblje. Stoga je i za regulatorno tijelo, za predstavnike reguliranih djelatnosti, jednako tako i za stručnu javnost od velike važnosti i pomoći bilo raspraviti neka pitanja i dileme iz predmetne problematike, i to upravo na skupu s predstavnicima raznih zainteresiranih strana.
In late 2006, the Croatian Energy Regulatory Agency adopted methodologies for the calculation of tariffs for the activities of the generation, transmission, distribution and supply of electricity, which until now have been components of a single tariff for an integrated system of the activities of the generation, transmission, distribution and supply of electricity. Pursuant to the legal obligations to separate these activities, as also expressed through the approach of the cited methodologies of the tariff systems, activities are in progress in reference to the calculation and adoption of tariff items for the aforementioned fundamental energy activities.
With the application of the cited methodologies, i.e. the adoption and coming into force of the new tariff systems of the electricity sector and the electricity sector of the Republic of Croatia, a new trial regulatory period will be entered. Therefore, for the regulatory agency, representatives of the regulated entities, and professional public, discussion of several questions and dilemmas from this area at a meeting among representatives of various interested parties was considered to be of great importance and benefit.
Ključne riječi: energetsko regulatorno tijelo, ekonomska regulacija, metoda priznatih troškova, metodologija tarifnog sustava, regulacija stopom povrata
Key words: economic regulation, energy regulatory agency, method of recognized costs, regulation of the rate of return, tariff system methodology

# 1 UVOD

Na inicijativu SO C5 – Tržište električnom energijom i regulacija, IO HRO CIGRÉ, u Zagrebu je 15. svibnja 2007. godine održan Okrugli stol – Uloga regulatornog tijela u donošenju tarifnih sustava.

Okrugli stol organiziran je sa svrhom i ciljem da predstavnici regulatornih tijela i predstavnici reguliranih subjekata uz prisutnost stručne javnosti izlože svoja iskustva i poglede, odnosno rasprave problem uloge i postupanja regulatornog tijela te sadržaja ekonomske regulacije kada su u pitanju tarifni sustavi za proizvodnju, prijenos, distribuciju i opskrbu električnom energijom. Naravno, postoji bitna razlika između, s jedne strane proizvodnje i opskrbe električnom energijom kao primarno tržišnih djelatnosti, dakle djelatnosti izloženih konkurenciji, i s druge strane infrastrukturnih prirodnih monopolnih djelatnosti prijenosa i distribucije električne energije, koji su u pravilu regulirane djelatnosti. Zakonodavni i regulatorni okvir u kojem postoji jasno izražena obveza javne usluge opskrbe tarifnih kupaca taj kontekst može djelomično izmijeniti na način da energetske djelatnosti proizvodnje i opskrbe električnom energijom i nadalje ostaju predmetom ekonomske regulacije i nadzora energetskog regulatornog tijela. Tako su u ovom slučaju sve četiri navedene usluge stavljene u kontekst općeg ekonomskog (gospodarskog) interesa i povjerena jednom poduzeću, da bi se osigurala sigurna, redovita i kvalitetna opskrba energijom po razumnim cijenama, vodeći računa o zaštiti okoliša. U svakom slučaju, problematika odabira pristupa i utvrđivanja metodologije ekonomske regulacije i donošenja odgovarajućih tarifnih sustava za svaku od navedenih energetskih djelatnosti, koje su ranije bile uključene u integrirani tarifni sustav, i na koje se sada trebaju primijeniti zasebni tarifni sustavi, stvara jedan potpuno novi problem koji je uz to praćen problemom efikasnog odvajanja energetskih djelatnosti. Dakako, sustavi i regulatorna tijela drugih zemalja bili su suočeni i suočavaju se sa sličnim pitanjima i problemima. Stoga je bilo važno raspraviti neka pitanja i dileme iz predmetne problematike s predstavnicima raznih zainteresiranih strana, a poglavito je bilo važno čuti iskustva i stavove relevantnih eksperata iz europskih regulatornih tijela i zemalja s višegodišnjim iskustvom u ekonomskoj regulaciji, bilo da se radi o dugogodišnjim članicama EU, ili zemljama koje su tek nedavno postale članice EU.

# 1 INTRODUCTION

At the initiative of SC C5 – Electricity Markets and Regulation, the Croatian National Committee of CIGRÉ, the Round Table Discussion on the Role of the Regulatory Agency in the Adoption of Tariff Systems was held in Zagreb on May 15, 2007.

The Round Table Discussion was organized with the purpose and goal of providing the opportunity for representatives of the regulatory bodies and the regulated entities to present their experiences and views in the presence of the professional public, i.e. discuss the problem of the role and approach of the regulatory agency and the content of economic regulation regarding the question of the tariff systems for the generation, transmission, distribution and supply of electricity. Naturally, there are significant differences between the generation and supply of electricity as primary market activities, i.e. activities subject to competition on the one hand, and on the other hand the infrastructural natural monopolistic activities of the transmission and distribution of electricity, which as a rule are regulated activities. The legislative and regulatory framework in which there are clearly expressed public service obligation supplying tariff customers can partially alter this context in that the energy activities of the generation and supply of electricity continue to remain subject to economic regulation and supervision by the energy regulatory agency. All four of the stated services are considered to be of general economic interest and entrusted to a single enterprise in order to assure a reliable, regular and quality energy supply at reasonable prices, while taking environmental protection into account. In any case, the problems of selecting an approach, determining a methodology for economic regulation and adopting the suitable tariff systems for each of the cited energy activities that were previously included within an integrated tariff system, for which it is now necessary to apply separate tariff systems, create a completely new problem which is accompanied by the problem of the effective separation of energy activities. Certainly, the systems and regulatory agencies of other countries have been confronted with similar questions and problems. Therefore, it was important to discuss certain questions and dilemmas regarding this topic with representatives of various interested parties and it was especially important to hear about the experiences and positions of relevant experts from the European regulatory agencies and countries with many years of experience in economic regulation, whether longstanding members of the European Union or countries that have only recently become members of the EU.

U radu Okruglog stola po pozivu su uz prezentacije i predavanja, te kroz diskusije različitih uloga i nadležnosti regulatornih tijela, ali i praktičnih pristupa regulaciji i problemu donošenja tarifnih sustava, sudjelovali predstavnici regulatornih tijela Francuske, Austrije, Slovenije, Mađarske i Hrvatske, te predstavnici Hrvatske elektroprivrede d.d., odnosno predstavnici energetskih subjekta u Republici Hrvatskoj za koje se donose i primjenjuju odgovarajući tarifni sustavi. Okrugli stol pobudio je veliki interes stručne javnosti i intenzivnu diskusiju problema i sadržaja uloge regulatornog tijela kada su u pitanju regulatorni pristupi i metode ekonomske regulacije energetskih djelatnosti, dakako onih energetskih djelatnosti koji imaju monopolne pozicije ili kojima su pridijeljene obveze javnih usluga. Interes za teme metodologija tarifnih sustava, strukture, utjecajnih parametara, podloga i dokaza za utvrđivanje razine tarifnih stavki i inače pobuđuju veliki interes, što se očitovalo i na ovom Okruglom stolu.

## 2 OSNOVNI ZAKONODAVNI OKVIR EU ZA USPOSTAVU TRŽIŠTA ELEKTRIČNE ENERGIJE I SADRŽAJ REGULACIJE

Ključni akti Europske komisije koji definiraju opći okvir osnivanja i rada energetskih regulatornih tijela, odnosno utvrđuju opće smjernice i standarde organizacije energetskog tržišta i nadležnosti tih tijela u svezi električne energije su:

– Direktiva 2003/54/EZ Europskog parlamenta i Vijeća ministara o općim pravilima za unutrašnje tržište električne energije i prestanku važenja Direktive 96/02/EZ, koja utvrđuje opća pravila za proizvodnju, prijenos, distribuciju i opskrbu električnom energijom, te definira pravila o organizaciji i funkcioniranju elektroenergetskog sektora, pristupa tržištu, kriterije i postupke koji se primjenjuju za objavu nadmetanja i davanje odobrenja i upravljanje sustavima,
– Direktiva 2003/55/EZ Europskog parlamenta i Vijeća o zajedničkim pravilima unutarnjeg tržišta prirodnog plina i ukidanju Direktive 98/30/EZ, koja utvrđuje zajednička pravila za prijenos, distribuciju, opskrbu i skladištenje prirodnog plina, LNG-a i druge tipove plinova koji se mogu tehnički i sigurno ubacivati i transportirati kroz sustav za prirodni plin, te definira pravila o organizaciji i funkcioniranju sektora, pristupa tržištu, kriterije i postupke

In the Round Table Discussion, in addition to invited presentations, lectures and the discussion of the various roles and authorities of regulatory agencies, as well as practical approaches to regulation and the adoption of tariff systems, representatives of the regulatory agencies of France, Austria, Slovenia, Hungary and Croatia as well as representatives of Hrvatska elektroprivreda d.d., i.e. representatives of the energy entities in the Republic of Croatia who adopt and apply the corresponding tariff systems, also participated. The Round Table Discussion aroused great interest among the professional public and provoked intense discussion on the problem and content of the role of the regulatory agency regarding regulatory approaches and methods for the economic regulation of energy activities, i.e. those energy activities that have a monopoly position or to whom the public service obligation has been assigned. The topics of the methodologies of the tariff systems, the structure, influential parameters, basis and evidence for the determination of various tariff items attract great interest generally, which was also apparent at this Round Table Discussion.

## 2 THE BASIC LEGISLATIVE FRAMEWORK OF THE EUROPEAN UNION FOR THE ESTABLISHMENT OF AN ELECTRICITY MARKET AND THE CONTENT OF REGULATION

The key acts of the European Commission that define the general framework for the establishment and activity of energy regulatory agencies, i.e. determine the general guidelines and standards for the organization of the energy market and the authorities of these bodies in connection with electricity, are as follows:

– Directive 2003/54/EC of the European Parliament and of the Council of Ministers on Common Rules for the Internal Market in Electricity and Repealing Directive 96/02/EC, that determines the general rules for the generation, transmission, distribution and supply of electricity and defines the rules on the organization and function of the electricity sector, market approach, the criteria and processes that are applied for announcing tendering procedures, issuing authorizations and managing systems,
– Directive 2003/55/EC of the European Parliament and of the Council Concerning Common Rules for the Internal Market in Natural Gas and Repealing Directive 98/30/EC, which determines the common rules for the transmission, distribution, supply and storage of natural gas, liquefied

koji se primjenjuju na davanje odobrenja i rad sustava,

– Uredba 1228/2003/EZ Europskog parlamenta i Vijeća o uvjetima pristupa mreži za prekograničnu razmjenu električne energije, te
– Uredba 1775/2005/EZ o uvjetima pristupa transportnim mrežama za prirodni plin.

Unutar tog općeg zakonodavnog okvira regulatornom tijelu mogu se dodijeliti različite nadležnosti i odgovornosti, odnosno poslovi. Na Okruglom stolu prezentacijama i raspravom primarno su bile obuhvaćene nadležnosti i uloga regulatornog tijela u pogledu donošenja metodologija tarifnih sustava i/ili određivanja tarifa/naknada za energetske usluge, odnosno krajnje kupce. Neposredno u svezi s tim prezentirani su i raspravljeni i mogući pristupi reguliranju monopola ili javnih usluga (cijena korištenja mreže, uvjeta pristupa mrežama, pravila za vođenje sustava, uvjeta osiguranja stabilnosti i pouzdanosti sustava, pravila i uvjeta osiguranja pomoćnih usluga sustava). Širom raspravom bile su obuhvaćene i ostale nadležnosti i poslovi koji se u pravilu dodjeljuju regulatornom tijelu, kao što su nadzor standarda kvalitete i izvedbe, kreiranje i provođenje općih uvjeta, propisa i standarda, reguliranje ulaska energetskih subjekata u sektor (dozvole, povlašteni statusi, priključenja, nova izgradnja) i nadzor nad tržištem, izvještavanje, savjetovanje vlade, ministarstava, javnosti, rješavanje žalbi na rad operatora sustava i rješavanje žalbi i sporova kupaca.

Na Okruglom stolu jasno je pokazano da je unutar tog jednog općeg zakonodavnog okvira svaka zemlja članica EU razvila i uspostavila vlastiti zakonodavni i regulatorni okvir za tržište električne energije i rad nacionalnog regulatornog tijela, temeljeći rješenja i praksu na važećem osnovnom nacionalnom pravnom i zakonodavnom sustavu. Opće je pravilo, a isto je više puta i u svim slučajevima ponovljeno na gotovo istovjetan način od strane predstavnika regulatornih tijela Francuske, Austrije, Slovenije, Mađarske i Hrvatske, sudionika Okruglog stola, da je cilj svake zemlje uspostaviti neovisno i efikasno nacionalno regulatorno tijelo koje će stvoriti uvjete i nadzirati razvoj i uspostavu razvidnog, efikasnog i nepristranog tržišta električne energije i plina na dobrobit svih sudionika tih tržišta i krajnjih korisnika. Preduvjeti razvidnog, efikasnog i nepristranog tržišta električne energije i plina su osiguranje i provedba razvidnog i nediskriminirajućeg pristupa energetskim mrežama po unaprijed poznatim, reguliranim uvjetima, neovisan i nepristran rad operatora energetskih sustava, razvidno i nepristrano rješavanje sporova i prigovora na pristupe mrežama i rad operatora mrežnih sustava, efikasna provedba i garancije računovodstvenog i upravljačkog

natural gas (LNG) and other types of gases that can technically and safely be injected into and transported through the natural gas system, and defines the rules on the organization and function of the sector, market access, criteria and procedures that are applicable to the granting of authorizations and the operation of the system,

– Regulation 1228/2003/EC of the European Parliament and of the Council on Conditions for Access to the Network for Cross-Border Exchanges in Electricity, and
– Regulation 1775/2005/EC of the European Parliament and of the Council on Conditions for Access to the Natural Gas Transmission Networks.

Within this general legislative framework, various authorizations and responsibilities, i.e. tasks can be assigned to a regulatory agency. At the Round Table, the presentations and discussions were primarily about the authorities and roles of the regulatory agency regarding the adoption of methodologies for tariff systems and/or determining tariffs/charges for energy services, i.e. the final customers. In connection with this, potential approaches to the regulation of monopolies or public services were presented and discussed (the cost of network use, conditions for network access, rules for system management, conditions for assuring the stability and reliability of a system, and rules and conditions for securing auxiliary system services). Broader discussions included other authorities and tasks that as a rule are assigned to the regulatory body, such as the supervision of the standards for quality and implementation, the creation and implementation of general conditions, regulations and standards; regulation of the entry of energy entities into the sector (permits, privileged status, connections and new construction) and supervision over the market, reporting; advising the government, ministries and public; the settling of complaints regarding the work of the system operator, and customer complaints and disputes.

At the Round Table Discussion, it was clearly demonstrated that within this general legislative framework, each Member Country of the EU has developed and established its own legislative and regulatory framework for the electricity market and the work of the national regulatory agency, based upon the solutions and practice of the prevailing basic national legal and legislative system. As a general rule, which was repeated in all cases in a nearly identical manner in the presentations by the representatives of the regulatory agencies of France, Austria, Slovenia, Hungary and Croatia, i.e. the Round Table participants, the goal of every country is to establish an independent and efficient national regulatory agency that will create the conditions, supervise the development and establish transparent, efficient and nondiscriminatory electricity and gas markets for the benefit of all the

razdvajanja energetskih djelatnosti, sprječavanje međusobnih subvencioniranja reguliranih i nereguliranih djelatnosti unutar vertikalno ili horizontalno integriranih sustava, efikasan sustav prekograničnih razmjena, razvoj i uspostava efikasnih tržišnih mehanizama i slobodna tržišna utakmica itd.

S druge strane, činjenice i pojavnost su da regulatorna tijela u različitim zemljama imaju različite pozicije u odnosu na državna tijela i institucije, prvenstveno odgovarajuće vlade i ministarstva, te različite uloge i nadležnosti. U nekim zemljama regulatorna tijela su organizacijska jedinica ili dio ministarstva ili pod nadzorom ministarstva ili vlade. U drugim zemljama su ili značajno ili u potpunosti neovisna tijela. U nekim zemljama regulatorna tijela imaju nadležnost i obvezu nadzora provedbe podzakonskih akata, donošenja metodologija tarifnih sustava, davanja odobrenja na planove razvoja i planove investiranja reguliranih subjekata, nadzora provedbe ili primjene tarifnih sustava i tarifa, nadzora financijskog poslovanja, nadzora provedbe računovodstvenog i upravljačkog razdvajanja, nadzora kvalitete energetskih usluga, davanja odgovarajućih mišljenja i savjetovanja ministarstava i vlada o cijenama, tarifama, pitanjima uspostave energetskog tržišta i sl. U drugim zemljama nacionalna regulatorna tijela imaju jaču ulogu i nadležnosti, koje uključuju donošenje odgovarajućih podzakonskih akata, ali i poduzimanje odgovarajućih mjera, utvrđivanje tarifa i uvjeta pristupa mrežama, rješavanje sporova u svezi s pristupom mrežama i uvjetima korištenja mreža, rješavanje prigovora i žalbi na rad operatora mrežnih sustava, rješavanje prigovora i žalbi krajnjih kupaca i slično. Nisu zanemarivi i sustavi mjera i sankcija koje nekim regulatornim tijelima stoje na raspolaganju da bi osnažili svoje djelovanje i odluke.

Kada su u pitanju nadležnosti za definiranje i donošenje metodologija ekonomske regulacije, odnosno izbor, definiranje i donošenje osnovnog regulacijskog pristupa, metodologije tarifnog sustava i samih tarifa, uloge regulatornih tijela se razlikuju. Opet, u nekim zemljama regulatorna tijela imaju ključnu ulogu u svim segmentima procesa od definiranja metode regulacije i metodologije tarifnog sustava, nadzora poslovanja i revizije financijskih pokazatelja i izvješća energetskih subjekata, dubinske revizije i odobravanja troškova, definiranja i odobravanja ključnih regulacijskih i makroekonomskih parametara, primjene mehanizama javnog prezentiranja i očitovanja javnosti, odnosno korisnika i kupaca o iznosima tarifnih stavki itd. U drugim zemljama regulatornim tijelima dane su u nadležnost i obveze samo neka od navedenih prava, poslova i obveza. Najčešći

participants of these markets and the final customers. The prerequisites for transparent, efficient and nondiscriminatory electricity and gas markets are the assurance and implementation of transparent and nondiscriminatory access to the energy networks according to previously specified regulatory conditions, the independent and nondiscriminatory work of the energy system operators, the transparent and nondiscriminatory resolution of disputes and complaints regarding network access and the work of the network system operators, the efficient implementation and guarantee of the accounting and managerial unbundling of energy activities, the prevention of cross subsidies among regulated and unregulated activities within vertically or horizontally integrated systems, an effective system for cross-border exchanges, the development and establishment of efficient market mechanisms and free market competition etc.

Otherwise, the regulatory agencies in various countries have differing positions in relation to the state agencies and institutions, primarily the corresponding governments and ministries, and various roles and authorities. In some countries, the regulatory agencies are organizational units, parts of a ministry or under the supervision of a ministry or the government. In other countries, they are either considerably or entirely independent bodies. In some countries, the regulatory bodies have the authority and responsibility of supervising the implementation of bylaws, the adoption of the methodologies of the tariff systems, granting approval for the development and investment plans of the regulated entities, supervision over the implementation or application of tariff systems and tariffs, supervision over financial operations, supervision over the implementation of accounting and managerial unbundling, supervision over the quality of energy services, issuing suitable opinions and advising ministries and the government regarding prices, tariffs, questions regarding the establishment of the energy market etc. In other countries, the national regulatory agency has a strong role and powerful authority, including the adoption of suitable bylaws but also the undertaking of suitable measures for the determination of tariffs and conditions for network access, the settlement of disputes in connection with network access and conditions for network use, the settlement of complaints regarding the work of the network system operator, the settlement of complaints from the final customers etc. The system of measures and penalties that some regulatory agencies have at their disposal to enforce their activity and decisions is not insignificant.

When authorities are in question for the definition and adoption of methodologies for economic regulation, i.e. the selection, definition and adoption of the basic regulatory approach, methodologies of the tariff system and tariffs themselves, the roles of the

je slučaj da regulatorno tijelo ima obvezu i odgovornost za donošenje odgovarajuće metodologije tarifnih sustava, te nadzora poslovanja i troškova reguliranih subjekata. Regulatorna tijela u nekim zemljama daju mišljenja odgovarajućim ministarstvima i vladama u pogledu visine tarifnih stavki, u drugim zemljama imaju nadležnost utvrđivanja, odnosno reguliranja tarifnih stavki, što je u pravilu i cilj njihova osnivanja.

Konačno, nužno je ukazati i na treći aspekt ili razinu mogućih nadležnosti i odgovornosti regulatornih tijela. Tu treću razinu čine pristupi pojedinim segmentima ili problemima ekonomske regulacije kao što su problemi kriterija za pridjeljivanje i priznavanje razine operativnih troškova poslovanja, odobravanja i priznavanja investicija u nove objekte, postrojenja i instalacije, troškova kapitala, odnosno amortizacije i povrata na uložena sredstva, utvrđivanja odgovarajuće regulatorne baze i stope povrata na reguliranu imovinu, priznavanja odgovarajućih inflatornih utjecaja na troškove i tarife, utvrđivanja i priznavanja i drugih korektivnih faktora na troškove i tarife, te konačno i postupanja u slučaju viškova i manjkova prihoda na karaju regulacijskog perioda. Posebno je pitanje odnosa i postupanja prema kategorijama prihoda koji imaju obilježja profita. Naravno, za ovaj treći regulacijski aspekt vezana su i pitanja, odnosno problemi koliko dug regulacijski period ustanoviti, kada primijeniti jednostavne, a kada početi primjenjivati složene metode ekonomske regulacije.

Često je prisutna i dilema kada uvesti poticajnu regulaciju, kako složene regulacijske pristupe i mehanizme učiniti razumljivim, razvidnim i prihvatljivim svim sudionicima, naročito energetskim subjektima koji iste trebaju primijeniti i korisnike ili kupce na koje se isti odnose, i končano, kako osigurati da ti mehanizmi u sukcesivnom slijedu rezultiraju stabilnom i efikasnom strukturom tarifa i sl. Za mrežne infrastrukturne sustave i prirodne monopolne energetske djelatnosti uz navedene treba dodati i pitanja odgovornosti i načina osiguravanja pomoćnih usluga sustava, pokriće troškova gubitaka, odgovornosti za pravovremen i dostatan razvoj i izgradnju sustava, te izgradnju dostatnih prekograničnih kapaciteta. Dodatno, operatori prijenosnog i distributivnog sustava imaju i odgovornosti u pogledu uključivanja i osiguravanja uvjeta za rad postrojenja koja koriste obnovljive izvore energije.

regulatory agencies differ. In some countries, the regulatory bodies have a crucial role in all the segments of the process, including the definition of the method for regulation and the methodology of the tariff system, supervision over operations and the auditing of financial indices and reports of energy entities, in-depth auditing and approval of expenditures, the definition and approval of crucial regulatory and macroeconomic parameters, the application of mechanisms for presentations and statements to the public, i.e. users and customers, about the amounts of tariff items etc. In other countries, the regulatory agencies are granted the authority and responsibility for only some of the stated rights, activities and responsibilities. The most frequent case is that a regulatory agency has the obligation and responsibility for the adoption of a suitable tariff system methodology, together with the supervision of the operations and expenditures of the regulated entities. The regulatory bodies in some countries issue an opinion to the corresponding ministries and governments regarding the amounts of tariff items, and in other countries they have the authority to determine or regulate the tariff items, which as a rule is the purpose for their establishment.

Finally, it is necessary to draw attention to the third aspect or level of the potential authorities and responsibilities of regulatory bodies. This third level consists of approaches to individual segments or problems of economic regulation, such as the problems of the criteria for the allocation and recognition of the level of operational costs, approval and recognition of investments in new facilities, plants and installations; capital costs, i.e. depreciation and investment return, determination of the suitable regulatory basis and rate of return on regulated property, recognition of the impact of inflation on costs and tariffs; the determination and recognition of other corrective factors on costs and tariffs, and finally the procedure in the event of revenue surpluses and deficits at the end of the regulatory period. A particular question refers to the attitude and procedure toward the categories of revenue that have recorded profits. Naturally, questions are connected with this third regulatory aspect, i.e. problems regarding how long a regulatory period should be established, when simple methods should be applied and when it is necessary to begin to apply complex methods of economic regulation.

There is often the issue of when to introduce incentive regulation, how to make complex regulatory approaches and mechanisms understandable, transparent and acceptable to all the participants, especially energy entities who must apply them and the users or customers to which they refer, how to assure that these mechanisms successively result in a stable and efficient tariff structure etc. For network infrastructure systems and naturally monopolistic

## 3 RESTRUKTURIRANJE ELEKTROENERGETSKOG SEKTORA, REGULACIJA I TARIFNI SUSTAVI U REPUBLICI HRVATSKOJ

U uvodnom dijelu Okruglog stola detaljno je izložen kontekst energetskog zakonodavnog okvira i procesa restrukturiranja elektroenergetskog sektora, odnosno otvaranja tržišta električne energije i razvoja i uspostavljanja novog regulatornog okvira u Republici Hrvatskoj [1], [2] i [3]. U tom kontekstu i okružju donesene su i objavljene metodologije tarifnih sustava, a tek treba utvrditi odgovarajuće stavke za prijenos i distribuciju električne energije te proizvodnju i opskrbu električnom energijom s izuzetkom za povlaštene kupce.

Naime, temeljem vrijedećih zakona Hrvatska energetska regulatorna agencija (u daljnjem tekstu: Agencija) ima obvezu i odgovornost, nakon pribavljenog mišljenja energetskih subjekata za obavljanje čijih djelatnosti se primjenjuje tarifni sustav i Ministarstva gospodarstva, rada i poduzetništva (u daljnjem tekstu: Ministarstvo), u sektoru električne energije donijeti metodologije tarifnih sustava, odnosno tarifne sustave bez visine tarifnih stavki, i to za: 1) proizvodnju električne energije, s iznimkom za povlaštene kupce, 2) opskrbu električnom energijom, s iznimkom povlaštenih kupaca, 3) prijenos električne energije, 4) distribuciju električne energije, 5) utvrđivanje naknade za priključak na prijenosnu i distribucijsku mrežu, te povećanje priključne snage, 6) pružanje usluga uravnoteženja električne energije u elektroenergetskom sustavu.

Prethodno navedene metodologije moraju omogućavati ulaganja potrebna za razvoj mreže i ostale zahtjeve sukladno postojećim zakonima.

Temeljem vrijedećih zakona energetski subjekt za obavljanje čijih djelatnosti se primjenjuje tarifni sustav podnosi prijedlog visine tarifnih stavki Ministarstvu, koje nakon pribavljenog mišljenja Agencije predlaže iznose tarifnih stavki Vladi Republike Hrvatske. Vlada Republike Hrvatske utvrđuje visinu tarifnih stavki. Agencija provodi nadzor primjene tarifnih stavki i svih ostalih naknada.

Na Okruglom stolu detaljno je izložen kontekst utvrđivanja i sadržaja metodologija tarifnih sustava za proizvodnju električne energije, s iznimkom za povlaštene kupce, opskrbu električnom energijom, s iznimkom povlaštenih kupaca, prijenos električne energije i distribuciju električne energije. U nastavku slijedi prikaz do sada vrijedećeg

energy activities, is also necessary to add questions of responsibility and the manner of assuring auxiliary services for the system, covering losses, responsibility for the timely and suitable development and construction of the system, and the construction of adequate cross-border capacities. Additionally, the transmission and distribution system operators have responsibilities in respect to the inclusion and assurance of the conditions for the operation of the plants that use renewable energy sources.

## 3 RESTRUCTURING OF THE ELECTRICITY SECTOR, REGULATION AND TARIFF SYSTEMS IN THE REPUBLIC OF CROATIA

In the introductory part of the Round Table Discussion, the context of the legislative framework for energy and the process of the restructuring of the electricity sector, i.e. opening the electricity markets and the development and establishment of a new regulatory framework in the Republic of Croatia, were presented in detail [1], [2] and [3]. In this context and environment, methodologies for tariff systems were adopted and published, and it is necessary to determine the corresponding tariffs for the transmission and distribution of electricity and production and supply of electricity with exceptions for eligible customers.

Based upon the prevailing legislation, the Croatian Energy Regulatory Agency (henceforth: the Agency) has the obligation and responsibility, after obtaining the opinions of the energy to entities to whose activities the tariff system is applied, and the Ministry of the Economy, Labor and Entrepreneurship (henceforth: the Ministry), to adopt methodologies for the tariff systems in the sector of electricity, i.e. the tariff systems without the amounts of the tariff items, and this for 1) the generation of electricity, with the exception of eligible customers, 2) the supply of electricity, with the exception of eligible customers, 3) the transmission of electricity, 4) the distribution of electricity, 5) the determination of connection fee to the transmission and distribution networks, and increasing the installed capacity, and vi) providing the services of balancing electricity within the electricity system.

The previously cited methodologies must facilitate the investment necessary for the development of the network and other requirements, pursuant to the existing legislation.

Based upon the prevailing legislation, the energy entities to whose activities the tariff system is ap-

integralnog tarifnog sustava koji je bio na snazi više godina, razloga za njegovu promjenu, te općih značajki pristupa i kontekst regulatornih mehanizama tarifnih sustava u Republici Hrvatskoj koji su doneseni i stupili na snagu u prosincu 2006. godine [4], [5], [6] i [7]. Naravno, kroz sve te sadržaje odražava se i specifična pozicija i uloga hrvatskog energetskog regulatornog tijela – Agencije. Međutim, ogleda se i težina problema konteksta, odnosno opsega i sadržaja regulacije energetskih djelatnosti u sektoru električne energije.

Naime, nije naodmet ponoviti i činjenicu da se potreba za organizacijom Okruglog stola pojavila u momentu kada su u Republici Hrvatskoj donesena i stupila na snagu četiri nova tarifna sustava, bez visine tarifnih stavki, tj. metodologije za izračun zasebnih tarifnih stavki za djelatnosti proizvodnje, prijenosa, distribucije i opskrbe električnom energijom. Iste su do sada bile komponente jedinstvene tarife za integrirani sustav djelatnosti proizvodnje, prijenosa, distribucije i opskrbe električnom energijom, odnosno svih usluga povezanih s opskrbom električnom energijom krajnjih kupaca. Sukladno jasnoj zakonskoj obvezi razdvajanja navedenih djelatnosti, izraženih i kroz pristup spomenutim metodologijama tarifnih sustava, u tijeku su poslovi vezani uz izračun i donošenje tarifnih stavki za navedene temeljne energetske djelatnosti. Primjenom spomenutih metodologija, odnosno donošenjem i stupanjem na snagu novih tarifnih stavki elektroenergetski sektor i elektroenergetsko gospodarstvo Republike Hrvatske ući će u prvo regulatorno razdoblje.

Stoga je i za regulatorno tijelo, za predstavnike reguliranih djelatnosti, jednako tako i za stručnu javnost od velike važnosti i pomoći bilo raspraviti neka pitanja i dileme iz predmetne problematike, i to upravo na skupu s predstavnicima raznih zainteresiranih strana. Poglavito je bilo važno čuti iskustva i stavove relevantnih eksperata iz europskih regulatornih tijela i zemalja s višegodišnjim iskustvom u ekonomskoj regulaciji, bilo da se radi o dugogodišnjim članicama EU, ili zemljama koje su tek nedavno postale članice EU. U uvodnom dijelu predstavnici Agencije i reguliranih subjekata u Republici Hrvatskoj detaljno su predstavili ulogu Agencije kao regulatornog tijela, odabrane i primijenjene regulacijske pristupe i mehanizme, odnosno sadržaje i elemente metodologije tarifnih sustava koji su u Republici Hrvatskoj doneseni u prosincu 2006. godine za energetske djelatnosti prijenosa i distribucije električne energije te proizvodnje i opskrbe električnom energijom s iznimkom za povlaštene kupce [8], [9] i [10]. Okrugli stol pružio je izvrsnu prigodu za usporedbu i diskusiju hrvatskog zakonodavnog i regulatornog okružja, odnosno regulacijskog pristupa i meha-

plied submit a proposal for the amounts of the tariff items to the Ministry, which after obtaining the opinion of the Agency proposes the amounts of the tariff items to the Government of the Republic of Croatia. The Government of the Republic of Croatia determines the amounts of the tariff items. The Agency supervises the application of the tariff items and all other compensation.

At the Round Table Discussion, the context for the determination and content of the methodology of the tariff systems for the generation of electricity was presented in detail, with an exception for favored customers, as well as the supply of electricity, with an exception for favored customers, the transmission of electricity and the distribution of electricity. A presentation follows of the valid integrated tariff system that was in force for many years, the reasons for changing it, and the general characteristics of the approach and context of the regulatory mechanisms of the tariff system in the Republic of Croatia that were adopted in December 2006 and have gone into effect [4], [5], [6] and [7]. Naturally, the specific position and role of the Croatian Energy Regulatory Agency is reflected in all of this. However, the difficulty with the context of the problem, i.e. the range and content of the regulations of the energy activities in the electricity sector, are also reflected.

It is necessary to reiterate the fact that the need for the organization of the Round Table Discussion came at the moment when the Republic of Croatia had adopted and placed into force four new tariff systems, without specifying the amounts of the tariff items, i.e. the methodology for the calculation of the separate tariff items for the activities of the generation, transmission, distribution and supply of electricity. Until now, they were components of a single tariff for the integrated system of the activities of the generation, transmission, distribution and supply of electricity, i.e. all the services connected with the supply of electricity to final customers. Pursuant to the clear legal obligation for the separation of these activities, also expressed through the approach of the previously mentioned methodologies of the tariff system, work is in progress in connection with the calculation and adoption of the tariff items for these basic energy activities. Through the application of the previously mentioned methodologies, i.e. the adoption and going into force of the new tariff items of the electricity sector and the economy of the Republic of Croatia, a trial regulatory period will be entered.

Therefore, for the regulatory agency, the representatives of the regulated entities, and the professional public, it would be of great importance and benefit to discuss several questions and dilemmas regard-

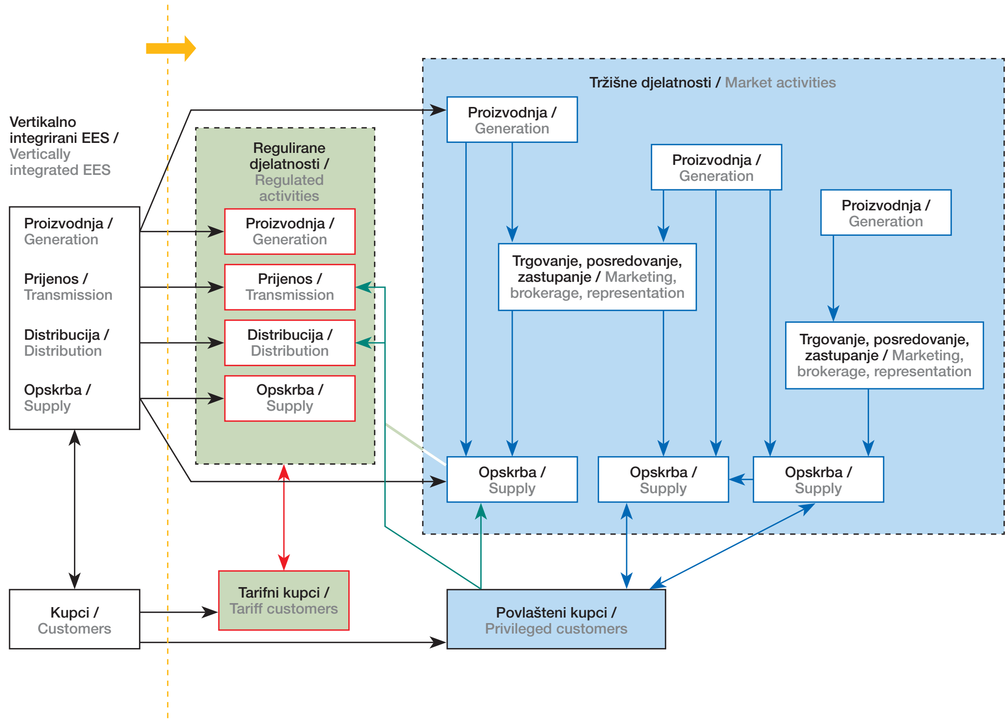
nizma, uključujući i sadržaje i elemente metodologije tarifnih sustava, s odgovarajućim okružjima, ulogama regulatornih tijela, odnosno pristupima, sadržajima i elementima regulacije i tarifnih sustava u Francuskoj, Austriji, Sloveniji i Mađarskoj i Hrvatske [11], [12], [13] i [14].

Na slici 1 prikazan je tijek procesa restrukturiranja elektroenergetskog sektora i tržišta električne energije, iz njegove vertikalno integrirane strukture u strukturu koja u svezi s tržišnim djelatnostima proizvodnje električne energije i opskrbe električnom energijom primarno podrazumijeva konkurentno okružje i tržišnu utakmicu, a glede monopolnih mrežnih infrastrukturnih sustava regulirano okružje po principu reguliranog pristupa treće strane, dakle po tarifama i ostalim uvjetima pristupa koji su unaprijed utvrđeni, razvidni i nepristrani. Specifična struktura regulacije i tarifnih sustava uvjetovana je zakonom utvrđenom obvezom javne usluge opskrbe električnom energijom tarifnih kupaca. Očito je da će tu specifičnu strukturu u budućnosti značajno uvjetovati dinamika otvaranja tržišta električne energije, tj. brzina kojom će se segment opskrbe i obveza prema tarifnim kupcima smanjivati, a segment povlaštenih kupaca rasti.

ing these problems at a meeting with the representatives of various interested parties. It would be especially important to hear about the experiences and positions of the relevant experts from the European regulatory bodies and countries with many years of experience in economic regulation, whether these countries that have been members of the EU for many years or have only recently become members of the EU. In the introductory section, representatives of the Agency and the regulated entities in the Republic of Croatia presented the role of the Agency in detail as a regulatory body, the chosen and applied regulatory approaches and mechanisms, i.e. the contents and elements of the methodologies of the tariff systems that were adopted in the Republic of Croatia in December 2006 for the energy activities of the generation of electricity, with an exception for favored customers, the supply of electricity, with the exception of favored customers, the transmission of electricity and the distribution of electricity [8], [9] and [10]. The Round Table Discussion provided an excellent opportunity for the comparison and discussion of Croatian legislation and the regulatory environment, i.e. the regulatory approach and mechanisms, including the contents and elements of the methodology of the tariff systems, with the corresponding environments, roles of the regulatory bodies, i.e. the approaches, contents and elements of the regulations and tariff systems in France, Austria, Slovenia, Hungary and Croatia [11], [12], [13] and [14].

In Figure 1, the process of the reconstruction of the electricity sector and the electricity market is presented, from its vertically integrated structure in a structure that in connection with the market activities of the generation of electricity and the supply of electricity is primarily understood to mean the competitive environment and market competition, and regarding the monopolistic network infrastructure systems, the regulated environment according to the principle of the third party acces according to tariffs and other conditions of access that have been determined in advance, and are transparent and nondiscriminatory. The specific structure of the regulatory and tariff systems was conditioned by the legally established public service obligation of the supply of electricity to tariff customers. It is evident that this specific structure will significantly affect the dynamics of the opening of the electricity market in the future, i.e. the speed at which the supply segment and the obligation toward tariff customers will be reduced and the segment of privileged customers will grow.

Slika 1
Restrukturiranje elektroenergetskog sektora i tarifni sustavi u Hrvatskoj
Figure 1
Restructuring of the electrical energy sector and the tariff systems in Croatia

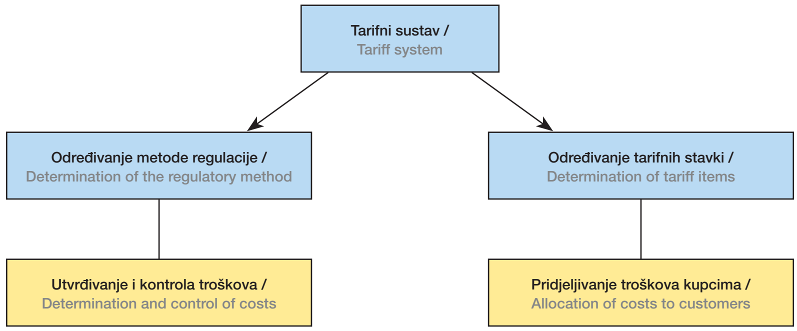



S druge strane izložena struktura ukazuje na to da je realno očekivati brze promjene konteksta, ali i sadržaja regulacije. Nije beznačajno ukazati i na dvojnost, bolje rečeno složenost regulatornog sadržaja koji s jedne strane proizlazi iz potrebe da se definiraju sadržaji i razrađuju specifični elementi ekonomske regulacije za segment tzv. prirodnih monopolnih djelatnosti prijenosa i distribucije električne energije, koje su u pravilu svugdje ujedno i regulirane djelatnosti, a s druge strane iz potrebe da se, premda ipak privremeno i do potpunog otvaranja tržišta električne energije, razviju i uvedu regulacijski mehanizmi za tržišne djelatnosti proizvodnje i opskrbe električnom energijom. Tržišne djelatnosti općenito i općeprihvaćeno trebaju biti izložene konkurenciji. To samo svjedoči o težini zadatka i izazova s kojima se suočava regulatorno tijelo, ali i regulirani subjekti, kada je proizvodnju i opskrbu potrebno prevesti iz stanja monopola u stanje konkurencije.

Na slici 2 prikazana je osnovna struktura, odnosno sadržaji novih tarifnih sustava kako ih definira novi zakonodavni okvir u Republici Hrvatskoj.

On the other hand, the presented structure indicates that it is realistic to anticipate rapid changes in the context as well as the contents of regulation. It is necessary to mention the duality, better to say the complexity, of the regulatory content that from the one side issues from the need to define the contents and work out the specific elements of the economic regulation of this segment, the so-called naturally monopolistic activities of the transmission and distribution of electricity, which as a rule are also regulated activities everywhere; and from the other side the need for, albeit temporarily and until the complete opening of the electricity market, the development and introduction of the regulatory mechanisms for the market activities of the generation and supply of electricity. Market activities should generally be exposed to competition. This only testifies to the difficulty of the task and the challenges confronting the regulatory agency, but also the regulated entities, when generation and supply must be changed from a state of monopoly to a state of competition.

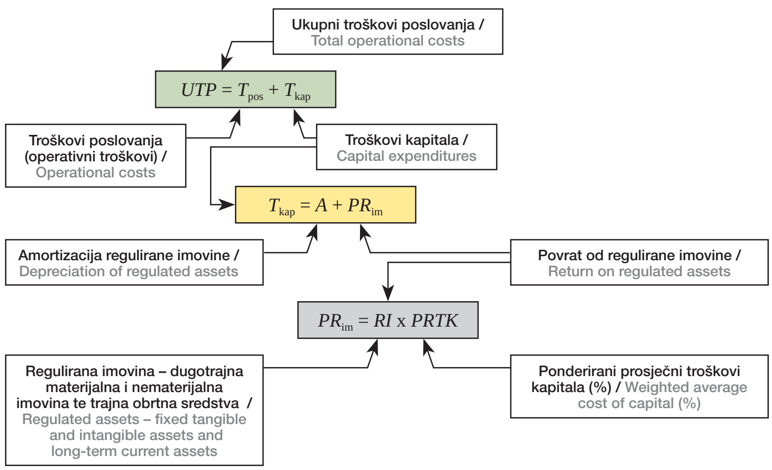
In Figure 2, the basic structure, i.e. content, of the new tariff systems is presented as defined by the new legislative framework in the Republic of Croatia.




**Slika 2**
Osnovna struktura i sadržaj novih tarifnih sustava
**Figure 2**
The basic structure and content of the new tariff systems

Ključni moment ili sadržaj regulacijskog procesa u kojem se definira pristup novom tarifnom sustavu je izbor osnovnog pristupa metodi regulacije (slika 3).

The crucial moment or content of the regulatory process in which the access to the new tariff system is defined is the selection of the basic approach to the method of regulation (Figure 3).




**Slika 3**
Izbor, sadržaj i mehanizam regulacije u novim tarifnim sustavima
**Figure 3**
The selection, content and mechanism of regulation in the new tariff systems

Ocjenjujući realnim i razumnim da se na početku prvog regulatornog razdoblja, dakle kada se po prvi put izlazi iz dugogodišnje integrirane tarifne strukture i jedinstvenih tarifnih stavki za sve energetske djelatnosti u sektoru električne energije i prelazi na odvojene pristupe i zasebne tarifne stavke za svaku od tih djelatnosti, odabere što jednostavniji, lakše primjenjiv i provedivi pristup i mehanizam, odabrana je opće poznata metoda priznatih troškova poslovanja, pri čemu se regulacija zapravo temelji i veže za kriterij stope povrata uloženog kapitala (eng. *Cost Plus* ili *Rate-of Return Regulation*). Dakle, slijedilo se odgovarajuće iskustvo i praksu više europskih zemalja i njihovih regulatornih tijela, koja su u početku procesa uvodila jednostavne regulacijske mehanizme, a

At the beginning of the first regulatory period, i.e. when for the first time the integrated tariff structure and single tariff items for all the energy activities in the power system will be replaced in transition to separate approaches and separate tariff items for each of these activities, it is realistic and reasonable to choose the simplest possible, easily applicable and feasible approach and mechanism. The generally known method of recognized costs of operations has been chosen, so that the regulation is actually based upon and connected with the criterion of the rate of return on investments. Furthermore, the corresponding experience and practice have been followed of several European countries and their regulatory agencies, which introduced simple regulatory mechanisms at the beginning of the process and then,

zatim s vremenom, kako su svi sudionici procesa stjecali odgovarajuća znanja i iskustva, uvodili sve složenije mehanizme, da bi danas primjenjivali složene mehanizme poticajne regulacije, ali i vrlo složene i zahtjevne procedure nadzora i kontrole svakog segmenta tih mehanizama. Tako npr. često su u regulacijske mehanizme uključeni neki od makroekonomskih gospodarskih parametara i pokazatelja, koji traže vrijeme za složenu i dugotrajnu analizu i elaboraciju. U pravilu se pokazuje da nije niti jednostavno niti opravdano bez ograde koristiti istovrsne pokazatelje primijenjene u drugim zemljama, pa čak niti prenositi i koristiti istovrsne pokazatelje primijenjene u drugim gospodarskim sektorima iste zemlje. Pogotovo je oprez nužan kada su u pitanju razina i struktura, odnosno način utvrđivanja odgovarajućih pokazatelja tržišnih rizika u svezi s ulaganjima, vlastitim kapitalom, dugovanjima i slično.

Zakon utvrđuje da se tarifni sustavi temelje na opravdanim troškovima poslovanja, održavanja, zamjene, izgradnje ili rekonstrukcije objekata i zaštite okoliša, uključujući razuman rok povrata sredstava od investicija u energetske objekte, uređaja i mreža, odnosno sustava, te moraju biti nepristrani i razvidni. Ujedno, tarifni sustavi trebaju poticati mehanizme za poboljšanje energetske učinkovitosti i upravljanje potrošnjom, uključujući i povećano korištenje obnovljivih izvora energije. Dakle, kod odabira temeljnog pristupa regulacije bilo je nužno voditi računa da prihod ostvaren primjenom novih tarifnih stavki treba pokriti sve priznate ukupne troškove poslovanja, dakle priznate operativne troškove i troškove kapitala, od kojih troškove kapitala čine amortizacija regulirane imovine i povrat od regulirane imovine.

U hrvatskoj literaturi često se miješaju dva različita pojma:

– kapitalni troškovi *(CAPEX, Capital Expenditures),*
– trošak kapitala *(CC, Cost of Capital, odnosno WACC, Weighted Average CC)*.

Reguliranom energetskom subjektu u općem slučaju treba omogućiti nadoknadu svih (priznatih) operativnih troškova, amortizacije, te troškova koje potražuju vlasnici financijskog kapitala, a to su:

– kamate i prinosi emitiranih korporacijskih obveznica,
– oportunitetni trošak vlasnika dioničarskog kapitala.

with time, when all the participants in the process had acquired the appropriate knowledge and experience, introduced progressively complex mechanisms in order to apply more complex mechanisms and incentive regulation today, but also highly complex and demanding procedures for the supervision and control of each segment of these mechanisms. Thus, for example, regulatory mechanisms frequently included some of the macroeconomic parameters and indices, which require time for complex and lengthy analysis and elaboration. As a rule, it has been shown that it is neither simple nor justifiable to use the same types of indices applied in other countries without limitation, or even to transfer and use the same types of indices applied in the other economic sectors of the same country. Caution is particularly necessary when the level and structure are in question, i.e. the manner of determining the corresponding indices of market risks in connection with investments, equity capital, debts etc.

The law establishes that the tariff systems are based upon the justified costs of the operations, maintenance, replacement, construction or reconstruction of facilities and environmental protection, including a reasonable period for the return of investments in energy facilities, equipment and networks, i.e. the systems, and must be nondiscriminatory and transparent. At the same time, tariff systems must promote mechanisms for the improvement of energy efficiency and the management of consumption, including the increased use of renewable energy sources. Therefore, in the selection of the basic approach to regulation, it was necessary to take into account that the income generated through the application of the new tariff items should cover all the known overall operational costs, i.e. the recognized operational costs and capital expenditures, which consist of the depreciation of the regulated property and the return from the regulated property.

In the Croatian literature, two different concepts are often confused:

– capital expenditures (*CAPEX*),
– cost of capital (*CC*, Cost of Capital, or *WACC*, Weighted Average *CC*).

Through the regulation of an energy entity in the general case, it is necessary to facilitate compensation for all (recognized) operative costs, depreciation and expenditures claimed by the owners of capital, as follows:

– interest and the income from corporate bonds issued,
– opportunity costs for stockholders.

Stopa povrata koja omogućuje naknadu troškova iz navedene dvije kategorije zove se ponderirani prosječni trošak kapitala *(WACC)*.

Po odabranom pristupu i metodi regulacije, određivanje visine tarifnih stavki za buduću regulacijsku godinu zasniva se na sljedećim troškovima:

a) priznatim ostvarenim troškovima poslovanja iz prethodne regulacijske godine,
b) ostvarenim i procijenjenim troškovima poslovanja za sadašnju regulacijsku godinu, te
c) prihvaćenim planskim vrijednostima troškova za razmatranu buduću regulacijsku godinu.

U reguliranu imovinu, temeljem koje se primjenom odgovarajuće priznate stope ponderiranog prosječnog troška kapitala računa povrat ili prinos od regulirane imovine, čine dugotrajna materijalna i nematerijalna imovina te trajna obrtna sredstva. Izložena osnovna struktura ili pristup primjenjuje se na sve djelatnosti: proizvodnju, prijenos, distribuciju i opskrbu električnom energijom.

Specifična temeljna struktura i osnovne stavke troškova poslovanja u svezi s proizvodnjom električne energije prikazana je na slici 4, u svezi s prijenosom električne energije na slici 5, s odgovarajućom posebnom razradom potrebnih podataka koja je prikazana na slici 6, u svezi s distribucijom električne energije na slici 7, te u svezi s opskrbom električnom energijom na slici 8.

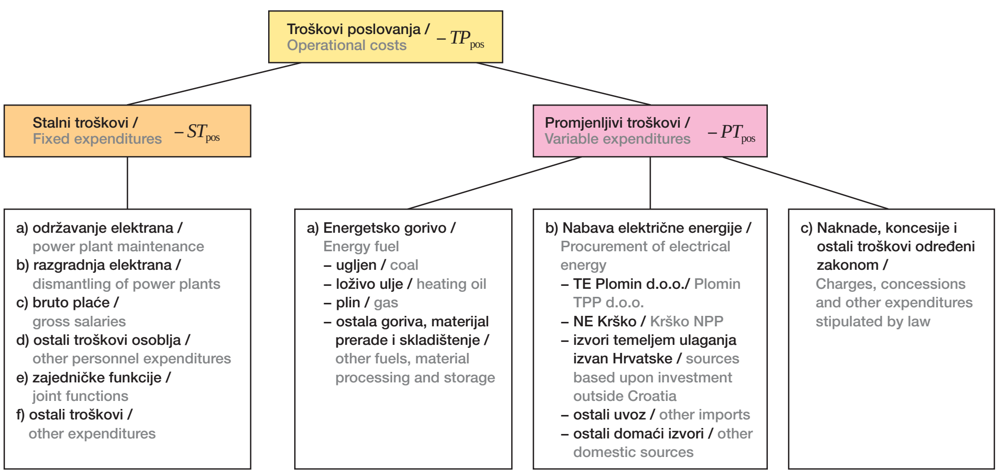
The rate of return that makes compensation for costs from the two cited categories possible is known as the weighted average cost of capital (WACC).

According to the selected approach and method of regulation, the determination of the level of the tariff items for the subsequent regulated year is based upon the following expenditures:

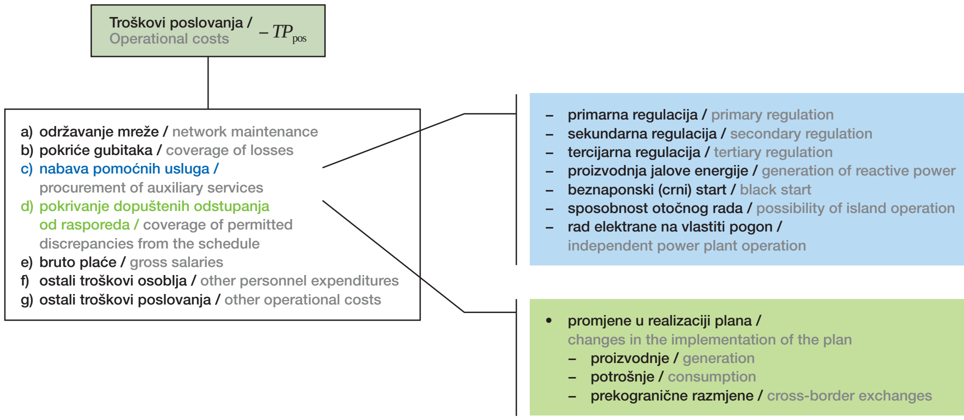
a) the recognized realized costs of operations during the previous regulated year,
b) the realized and estimated costs of operations for the current regulated year, and
c) the accepted planned values of expenditures for the analyzed subsequent regulated year.

For regulated property, according to which the corresponding recognized rate of the weighted average cost of capital is applied, the return or revenue is calculated and consists of fixed tangible assets, intangible assets and permanent current assets. The basic structure or approach presented is applied to all activities: the generation, transmission, distribution and supply of electricity.

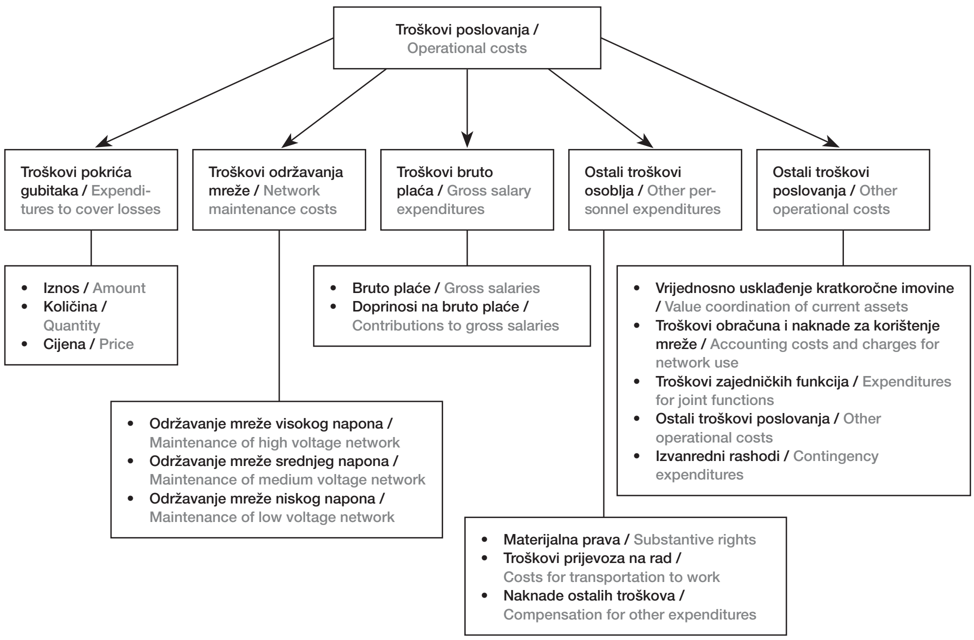
The specific fundamental structure and basic items of operational costs in connection with the generation of electricity are presented in Figure 4, in connection with the transmission of electricity in Figure 5, with the corresponding separate processing of the necessary data presented in Figure 6, the distribution of electricity in Figure 7 and in connection with the supply of electricity in Figure 8.



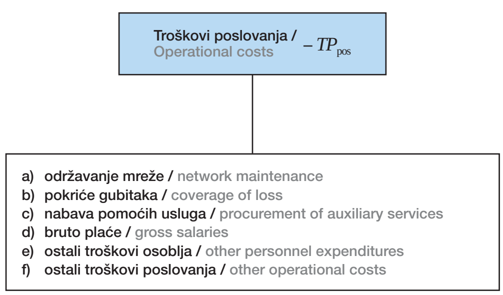

**Slika 4**
Tarifni sustav za proizvodnju električne energije (struktura troškova)
**Figure 4**
The tariff system for the production of electrical energy (the structure of expenditures)



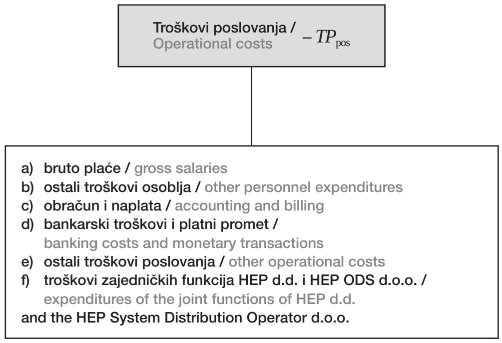

**Slika 5**
Tarifni sustav za prijenos električne energije (struktura troškova)
**Figure 5**
The tariff system for the transmission of electrical energy (the structure of expenditures)




**Slika 6**
Tarifni sustav za prijenos električne energije (struktura potrebnih podataka)
**Figure 6**
The tariff system for the transmission of electrical energy (the structure of the required data)




**Slika 7**
Tarifni sustav za distribuciju električne energije (struktura troškova)
**Figure 7**
The tariff system for the distribution of electrical energy (the structure of expenditures)




**Slika 8**
Tarifni sustav za opskrbu električnom energijom (struktura troškova)
**Figure 8**
The tariff system for the supply of electrical energy (the structure of expenditures)

Glede prijenosa električne energije, bolje rečeno HEP Operatora prijenosnog sustava problematiku pristupa regulaciji, odnosno tarifnom sustavu još složenijima čine i sljedeća pitanja, odnosno problemi novog okružja, kao što su:

- poslovanje HEP Operatora prijenosnog sustava na otvorenom tržištu,
- način utvrđivanja i tretmana troškova nastalih zbog prekograničnih tranzita električne energije,
- potreba da se u kratkom vremenu razradi trogodišnji plan razvoja i izgradnje u novom okružju i po novoj metodologiji (problem okvira i temeljnih odrednica za donošenje plana u znatno restrukturiranom okružju u koji se uvode tržišni odnosi, stvaraju pretpostavke za regulirani pristup trećih strana mrežama i uslugama sustava, ulaze novi sudionici, stvara novo poticajno okružje za veće korištenje obnovljivih izvora energije, jednom riječju mijenjaju dosadašnji tradicionalni odnosi i struktura odgovornosti),
- kako napraviti djelotvornu analizu osjetljivosti cijene za korištenje prijenosne mreže, koja sada postaje zasebna stavka,
- kako osigurati pomoćne usluge sustava i na razvidan i pravedan način pridijeliti ih korisnicima i naplatiti,
- kako obuhvatiti i na djelotvoran način analizirati utjecaj vjetroelektrana i drugih postrojenja koja koriste obnovljive izvore energije na pogonske parametre mreže, ali i na troškove korištenja prijenosne mreže,
- kako ustanoviti djelotvoran mehanizam proračuna troškova upravljanja zagušenjima mreže,
- da li ustanoviti odvojeno računovodstvo i kako, itd.

Glede distribucije električne energije, bolje rečeno HEP Operatora distribucijskog sustava problematiku pristupa regulaciji i tarifnom sustavu dodatno prati problematika nestandardnih usluga: njihova

Regarding the transmission of electricity, better to say the HEP Transmission System Operator, the problem of the approach to regulation, i.e. the tariff system, is further complicated by questions and problems of the new environment, including the following:

- the operations of the HEP Transmission System Operator on the open market,
- the manner of the determination and treatment of costs occurring due to the cross-border transit of electricity,
- the necessity of preparing a three-year development and construction plan in a short time within the new environment and according to new methodology (the problem of the framework and fundamental determinants for the adoption of the plan in the significantly restructured environment into which market relations are being introduced, creating the prerequisites for the regulated access of third parties to the system networks and services, the entry of new participants, the creation of a new incentive environment for the increased use of renewable energy sources, i.e. the traditional relationships and structure of responsibilities are changing),
- how to prepare an effective analysis of price sensitivity for the use of the transmission network, which presently represents a separate item,
- how to secure auxiliary system services, allocate them to users and charge for them in a transparent and fair manner,
- how to include and efficiently analyze the impact of wind power plants and other facilities that use renewable energy sources on the network operating parameters, but also on the costs of using the transmission network,
- how to establish an efficient mechanism for calculating the costs of the management of network congestion,
- whether and how to establish separate accounting etc.

Regarding the distribution of electricity, better to say the HEP Distribution System Operator, the problem of

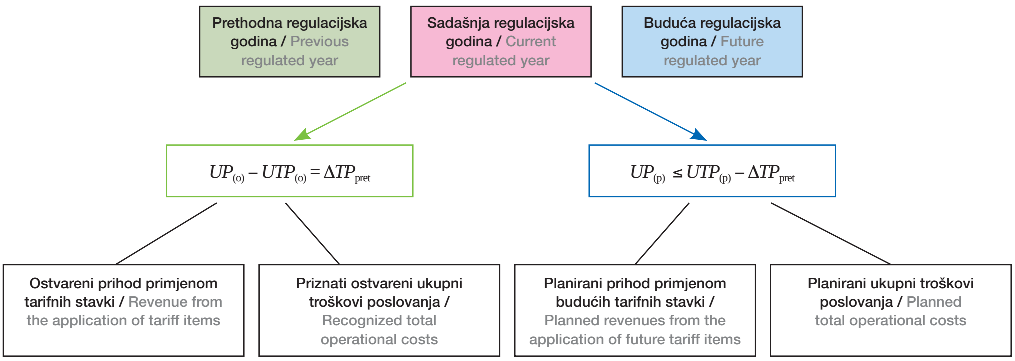
knjigovodstvenog praćenja po izdvojenim kontima i njihova odvajanja od standardnih usluga kod praćenja troškova. Problem je i rasporeda troškova prema njihovoj vrsti te utvrđivanja elemenata za proračun povrata na reguliranu imovinu.

Tijek procesa utvrđivanja i predlaganja visine tarifnih stavki prikazan je na slici 9.

the approach to the regulation and tariff system is additionally accompanied by the problem of nonstandard services; bookkeeping records according to separate accounts and their separation from "standard" services in monitoring expenditures. There is also the problem of the distribution of expenditures according to their type and the determination of the elements for the calculation of returns on regulated property.

The process for the determination and proposal of the amounts of the tariff items is presented in Figure 9.

**Slika 9**
Novi tarifni sustavi (proces predlaganja visine tarifnih stavki)
**Figure 9**
New tariff systems (the process of proposing the amounts of tariff items)




Prethodna godina je godina koja prethodi godini za koju se donose tarifne stavke za odgovarajuću energetsku djelatnost, a za koju su revidirani i objavljeni financijski podaci, poznat ukupni prihod primjenom vrijedećih tarifnih stavki i poznati ostvareni ukupni troškovi poslovanja. Sadašnja regulacijska godina je tekuća godina u kojoj se podnosi prijedlog promjene visine tarifnih stavki za buduću regulacijsku godinu. Prijedlog promjene visine tarifnih stavki za odgovarajuću energetsku djelatnost podnosi energetski subjekt na koji se te tarifne stavke odnose. Energetski subjekt dužan je uz prijedlog za promjenu visine tarifnih stavki dostaviti sve podatke potrebne za utvrđivanje troškova poslovanja, posebno financijsko izvješće za prethodnu regulacijsku godinu potvrđeno od ovlaštenog neovisnog revizora te plan poslovanja i plan razvoja i izgradnje (za sadašnju i buduću regulacijsku godinu). Navedeni dokumenti moraju biti potpisani od ovlaštene osobe energetskog subjekta i ovjereni pečatom tvrtke. Na zahtjev Ministarstva ili Agencije energetski subjekt dužan je dostaviti i druge podatke potrebne za utvrđivanje promjene visine tarifnih stavki te omogućiti uvid u pripadnu dokumentaciju. Prijedlog promjene visine tarifnih stavki za buduću regulacijsku godinu energetski subjekt dužan je dostaviti u sadašnjoj regulacijskoj godini, a nakon što za nju budu po-

The previous year is the year that precedes the year for which tariff items are adopted for the corresponding energy activity, and for which the financial data are revised and published: the known total revenue through the application of the valid tariff items and the known realized total operational costs. The current regulatory year is the current year in which a proposal is submitted for changing the amount of tariff items for the subsequent regulatory year. A proposal for a change in the amount of tariff items for the corresponding energy activity is submitted by an energy entity to which the tariff items apply. Together with the proposal for the change in the amount of tariff items, the energy entity is required to submit all data necessary for the determination of the operational costs, especially the financial report for the previous regulatory year audited by an authorized independent auditor, a plan of operations, and a plan of development and construction (for the current and future regulatory years). These documents must be signed by the authorized person of the energy entity and stamped with the company seal. At the request of the Ministry or Agency, the energy entity is required to submit other data necessary for determining the changes in the amounts of tariff items and facilitate the inspection of the corresponding documentation. A proposal for changes in the amount of tariff items for the subsequent regulatory year must be submit-

znati polugodišnji ukupni troškovi poslovanja. I konačno, energetski subjekt dužan je predložiti promjenu visine tarifnih stavki uz uvjet da očekivani prihod u budućoj regulacijskoj godini, izračunat prema odgovarajućem tarifnog sustava, ne prelazi prihvaćene planirane ukupne troškove poslovanja, korigirane za eventualna opravdana ili odobrena odstupanja.

Pored prethodnog bitno je istaći da su utvrđene i sljedeće obveze energetskih subjekata:

- rok za usklađivanje poslovanja s odredbama tarifnog sustava je šest mjeseci,
- obveza dostavljanja podataka, posebno plana poslovanja te plan razvoja i izgradnje, odnosno trogodišnjeg plana razvoja i izgradnje, kojeg subjekt donosi uz suglasnost Agencije, i to:
  - do 31. 5. sadašnje regulacijske godine – financijska izvješća za prethodnu regulacijsku godinu potvrđena od ovlaštenog neovisnog revizora,
  - do 30.11. sadašnje regulacijske godine - planovi poslovanja.

## 4 ZAKLJUČCI OKRUGLOG STOLA O ULOZI REGULATORNOG TIJELA U DONOŠENJU TARIFNIH SUSTAVA

Nakon svih prezentacija i rasprava u kojima su sudjelovali predstavnici regulatornih tijela iz Francuske, Austrije, Slovenije, Mađarske i Hrvatske, te predstavnici Hrvatske elektroprivrede d.d., odnosno predstavnici energetskih subjekta u Republici Hrvatskoj za koje se donose i primjenjuju odgovarajući tarifni sustavi, utvrđeni su zaključci Okruglog stola. Ti zaključci su bili kako slijedi:

1) Okrugli stol uspješno je organiziran i proveden i u potpunosti je opravdao razloge organiziranja, ponudivši niz odgovora na važna pitanja i dileme glede pristupa, sadržaja i forme regulacije, provedbenih procedura i metodologija regulacije, metodologija tarifnih sustava i strukture samih tarifnih stavki. Naravno, sudionici nisu propustili naglasiti i pojasniti niz provedbenih ili proceduralnih, dakle pojavnih i praktičnih problema s kojima se susreću regulatorna tijela i regulirani energetski subjekti, naročito oni koji su nositelji monopolnih djelatnosti i obveza javnih usluga.

2) Predavači su sudionike Okruglog stola uveli u predmetnu problematiku i ukazali im na opću prisutnost sličnih pitanja i dilema u svim zemlja-

ted by an energy entity during the current regulatory year, and after it knows the total operational costs for the first half of the year. Finally, the energy entity is required to propose a change in the amount of tariff items under the condition that the anticipated revenue in the subsequent regulatory year, calculated according to the corresponding tariff system, does not exceed the accepted planned total operational costs, corrected for eventual justified or authorized discrepancies.

In addition to the above, it is essential to emphasize that the following obligations of energy entities have also been determined:

- the deadline for the coordination of operations with the provisions of the tariff system is six months,
- the obligation for the submission of data, especially a plan of operations and a plan for development and construction, i.e. a three-year plan for development and construction, that the subject adopts with the approval of the Agency, as follows:
  - by May 31 of the current regulatory year – financial reports for the previous regulatory year that have been audited by an authorized independent auditor, and
  - by November 30 of the current regulatory year – operational plans.

## 4 CONCLUSIONS OF THE ROUND TABLE DISCUSSION ON THE ROLE OF THE REGULATORY BODY IN THE ADOPTION OF NEW TARIFF SYSTEMS

Following all the presentations and discussions in which the participants were the representatives of the regulatory agencies of France, Austria, Slovenia, Hungary and Croatia; representatives of Hrvatska elektroprivreda d.d., and representatives of the energy entities in the Republic of Croatia for whom the corresponding tariff systems are being adopted and applied, conclusions were reached by the Round Table, as follows:

1) The Round Table was organized and conducted successfully. It fully justified the reasons for which it was held, providing a range of answers to important issues and dilemmas related to the approach, regulatory contents and form, implemented procedures, regulatory methodology, tariff system methodology and the structure of the tariff items themselves. The participants emphasized and explained a range of implementational or procedural issues, i.e. actual and practical issues that the regulatory agencies and regulated entities encounter, especially those with monopolies and public service obligations.

ma, kod svih regulatornih tijela i svih reguliranih energetskih subjekata. Naravno, u zemljama u kojima su odgovarajuća energetska regulatorna tijela osnovana tek nedavno, u kojima određeni procesi restrukturiranja i novog organiziranja elektroenergetskog sektora nisu u potpunosti dovršeni, u kojima je proces otvaranja tržišta električne energije i uvođenje konkurencije tek u početnoj fazi, i konačno u kojima odgovarajuće makroekonomske pokazatelje i utjecajne regulatorne parametre nije nimalo lako i jednostavno utvrditi, puno je veći broj i pitanja i dilema. Oblik prenošenja znanja i stečenih iskustava, kakav je uostalom ponudio i ovaj Okrugli stol, ukazuje na nužnost i potrebu organizacije istih ili sličnih formi i sadržaja rada na nacionalnoj, regionalnoj, pa i široj međunarodnoj razini, bilo da se radi o okruglim stolovima, radionicama, seminarima ili konferencijama.

**3)** Okrugli stol naglasio je da je bez obzira na različita iskustva i dinamiku procesa, i bez obzira na opći zakonodavni i gospodarski sustav iz kojeg dolazi, odgovarajući vrijedeći zakonodavni okvir u svakoj državi mora osigurati uvjete za nezavisan, nepristran i razvidan rad energetskog regulatornog tijela. Unutar toga zakonodavnog okvira nadležno državno tijelo i regulatorno tijelo imaju obvezu i dužnost izgraditi i primijeniti utemeljene, realne, razvidne i lako provedive mehanizme i metodologije regulacije, odnosno metodologije tarifnih sustava. O raznim oblicima ili sadržajima, političkim i gospodarskim utjecajima nužno je voditi računa utoliko što su oni stalno prisutni, što su izrazi raznih nacionalnih strategija ili interesa, dakle predstavljanju važan element realnog okružja u kojem se odvija život i rad regulatornog tijela i reguliranih energetskih subjekata, i u kojem se uspostavlja tržište električne energije.

**4)** Okrugli stol naglasio je suštinsku uvjetovanost problema regulacije reguliranih energetskih djelatnosti, naročito monopolnih mrežnih sustava i javnih usluga dinamikom otvaranja i načinom uređenja tržišta električne energije. Pravo pristupa mrežama i pomoćnim uslugama sustava prvo je u nizu problema s kojima se treba susresti. Nema dvojbe da se pravo pristupa treba i mora urediti unaprijed kroz odgovarajuća mrežna pravila i tehničke uvjete, ali da bi se moglo ostvarivati u nepristranom, razvidno i nediskriminirajućem okružju, nužno je unaprijed utvrditi i objaviti i tehničke i ekonomske uvjete priključka i naknade za korištenja prijenosne i distribucijske mreže, te uvjete i naknade za korištenje pomoćnih usluga sustava, naravno u slučaju da su iste obuhvaćene odgovarajućim regulatornim okvirom.

**5)** Okrugli stol jasno je pokazao prednost u iskustvu i rješenjima regulatornih tijela, odnosno

**2)** The lecturers introduced the issues to the Round Table Discussion participants and called attention to the general presence of similar questions and dilemmas in all the countries, regulatory agencies and regulated electrical power entities. Naturally, there are many more questions and dilemmas in countries where the energy regulatory agencies have only been recently established and certain processes of the restructuring and reorganizing of the electricity sector have not been fully completed, where the processes of opening the electricity market and the introducing of competition are in the initial phases and, finally, where the corresponding macro-economic indices and influential regulatory parameters are not easy to determine. The form of the transfer of knowledge and acquired experience, as provided at this Round Table Discussion, indicates the necessity for organizing similar events at the national, regional and even international levels, in the form of round table discussions, workshops, seminars or conferences.

**3)** The Round Table Discussion emphasized that, regardless of differences in experiences and process dynamics, and regardless of the general legal and economic system, the appropriate valid and transparent legal framework in each country must provide conditions for the independent, nondiscriminatory and transparent operation of the energy regulatory agency. Within this legal framework, the authorized government agency and regulatory agency have the obligation and duty to build and implement well-founded, realistic, transparent and feasible regulatory mechanisms and tariff system methodologies. It is necessary to take the various forms and contents of the prevailing political and economic influences into account, which are expressions of various national strategies or interests, i.e. they represent an important element of the actual environment in which the regulatory agency and the regulated electrical power entities function, and in which the electricity market is established.

**4)** The Round Table Discussion highlighted an essential correlation among the issues of the regulation of regulated activities, especially monopolistic network systems and public services, in the dynamics of the opening of electricity markets and the manner of their organization. The right to access the networks and auxiliary services of the system is the first in a series of issues that must be addressed. There is no doubt that the right to access must be defined in advance through appropriate network rules and technical conditions. In order for this right to be exercised in an nondiscriminatory, transparent and non-discriminatory environment, it is necessary to predetermine and publish the technical and economic prerequisites for electricity connections, charges for using the transmission and distribution networks, and the conditions and charges for the use of the

država i njihovih odgovarajućih energetskih sektora i gospodarskih subjekata, koji su u spomenute procese i problematiku ušli ranije. S druge strane, prednost zemalja, njihovih energetskih sustava i gospodarstava, dakako i njihovih regulatornih tijela, koji su procese otvaranja tržišta električne energije i uvođenja novih oblika regulacije započeli tek nedavno, da mogu koristiti odgovarajuća iskustva zemalja u kojima su tržišta električne energije uspostavljena i razvijena ranije, i kojima je regulacija ušla u više faze i razdoblja primjene, pri tom ne ponavljajući njihove zablude i kriva rješenja.

6) U pogledu regulacije energetskih djelatnosti prednost je država i ekonomija, uključujući i energetski sektor, koji imaju dobro praćenje i izvještavanje o adekvatnim makroekonomskim gospodarskim parametrima, kao što su interesne, odnosno kamatne stope na vlastiti kapital i zaduženja, stope inflacije, premije na tržišne rizike, prinose od rizičnih i nerizičnih ulaganja, pokazatelje u svezi s prinosom dionica, premije za tržišni rizik vlastitog kapitala itd. Jednoznačni prijenos i primjena navedenih parametara iz jednog nacionalnog u drugi nacionalni energetski gospodarski sustav ili regulatorni okvir vrlo je dvojben i prati ga niz pitanja i dvojbi. Tim više što ne samo da nema jednoznačnih kriterija, nego su i vrlo različiti pristupi utvrđivanju osnovica, npr. vrijednosti imovine i regulatorne osnovice, na koje se navedeni parametri primjenjuju. U tom kontekstu i ciljani financijski pokazatelji, kao što je to npr. stopa povrata na imovinu ili pak garantirani vremenski rok povrata uloženih sredstava, u posljednje vrijeme sve češće postaju predmetom preispitivanja, nerijetko čak i važno političko pitanje na nacionalnoj razini. Naime, s navedenim pitanjima usko su povezani problemi novih investicija i ulaganja u elektroenergetske sustave, ali i pitanja profita iz energetskih djelatnosti. Svaki od navedenih ekonomskih veličina i parametara dakako ima svoj odraz u odgovarajućem utjecaju na ekonomičnost poslovanja energetskog subjekta i njegovu sposobnost da se dalje razvija.

U okviru diskusije konstatirano je da bi bilo dobro i pragmatično da prve razvojne faze ekonomske regulacije prate i relativno jednostavne regulacijske sheme tipa *cost plus* ili povrata sredstava, da bi nakon stjecanja određenih iskustava i znanja uslijedio razvoj puno složenijih shema koje uključuju kombinacije tehničkih i ekonomskih inicijativa koje kroz dugoročni period trebaju osigurati sigurno i stabilno financiranje rada i adekvatni razvoj reguliranih energetskih subjekta, naročito velikih mrežnih infrastrukturnih sustava za prijenos i distribuciju električne energije. Opći konačni cilj je dakako sigurna opskrba električnom energijom po realnoj, odnosno opravdanoj cijeni.

auxiliary system services in the event that these are covered by the corresponding regulatory framework.

5) The Round Table Discussion clearly demonstrated the superiority of the experience and solutions of the regulatory bodies, countries, energy sectors and economic entities which had addressed these processes and problems earlier. On the other hand, the countries, energy systems, economies and certainly regulatory agencies that have only begun the processes of opening the electricity markets and introducing new forms of regulations have the advantage of being able to utilize the experiences and avoid repeating the past errors and inadequate solutions of the countries in which the electricity markets have already been established and developed, and in which regulations have entered advanced phases and periods of application.

6) In the regulation of energy activities, the governments and economies, including the energy sectors, that have good tracking and reporting of macroeconomic parameters such as interest rates on equity and debt, inflation rates, market risk premiums, yields from high-risk and low-risk investments, indices in connection with stock market yields, equity-risk premiums etc. are at an advantage. The direct transfer and application of these parameters from one national power system or regulatory framework to another is not practicable because a number of issues and dilemmas are involved. This is even more the case because there are no uniform criteria. Instead, there are highly varied approaches for the determination of the bases, for example the asset-value base and regulatory base to which the given parameters are applied.

In this context, the target financial indices such as the rate of return on assets or the guaranteed period of return on investment have lately become subjected to increasing scrutiny and are frequently an important political issue at the national level. Closely related to these issues are the problems of new investments in power systems, as well as the question of profit from electricity activities. Each of these economic measurements and parameters certainly influence the cost-effectiveness of the operations of entities and their ability to continue to develop.

Within the framework of the discussion, it was concluded that it would be good and pragmatic for the first development phases of economic regulation to accompany relatively simple regulation schemes of the “cost plus” or “return on assets” type. After experience and knowledge are acquired, this should be followed by the development of more complex schemes that include a combination of technical and economic initiatives, which over the long run should assure the secure and stable financing of operations

7) Regulatorna tijela imaju važnu ulogu u procesu odobravanja i nadzora provedbe razvojnih planova reguliranih subjekata, tj. prijenosne i distribucijske mreže i sustava, odnosno nadzornu ulogu u pogledu kvalitete i sigurnosti usluga i funkcija koje obavljaju ti energetski subjekti, ali i opskrbe krajnjih kupaca i korisnika u cjelini. Pristupi i praksa u različitim zemljama razlikuju se.

Ima primjera duboke uključenosti i odgovornosti regulatornog tijela u svim fazama i elementima planiranja (odobravanje i nadzor provedbe planova), osiguranja sredstava kroz naknade i poticajne elemente tih naknada (kapitalni troškovi, povrati na kapital), te općeg procesa nadzora rada reguliranog energetskog subjekta. S druge strane, uloge nekih regulatornih tijela u početku nisu podrazumijevala obilježja duboke uključenosti. Nadomjestak dubljem regulatornom nadzoru bili su opći pristupi po kojim su npr. planirane investicije iz razvojnih planova i planova izgradnje bile odobravane do određene razine i kao takve uključene u naknade za korištenje mreže. Ima primjera i manje involviranosti regulatornog tijela u početnim fazama uvođenja regulacije ili tijekom početnih regulatornih perioda. Međutim, odmakom procesa i sve većom involviranosti regulatornog tijela u više slučajeva dovelo je do smanjenja naknada za korištenje mreža.

8) Navedeni tijek gotovo u potpunosti poklapa se s tijekom uvođenja složenih regulatornih pristupa i metodologija ekonomske regulacije, odnosno metoda poticajne regulacije energetskih djelatnosti. Iz svega prethodnog izveden je zaključak da se u početku trebaju što bolje i preciznije definirati odgovornosti regulatornog tijela i reguliranih subjekata. Nadalje, u novonastalim i tržišnim okolnostima trebaju se dobro obuhvatiti i obrazložiti svi važni parametri, utjecajne veličine i okolnosti tržišnog okružja koje se uvodi, Posebno je važno krenuti s jednostavnijim regulatornim pristupima i metodama, i to u pravilu s kraćim regulatornim periodima. Svaka od mogućih nesigurnosti ili skrivenih mana u regulatornom pristupu, krivo procijenjenog utjecajnog parametra ili ciljanog ekonomskog indeksa, nepredviđene loše posljedice procesa restrukturiranja u dinamičnom tržišnom okružju, ali na kraju i posljedice moguće krive odluke regulatornog tijela, vodi ili vrlo visokim ili nedopustivo niskim iznosima naknada za korištenje mreža. Visoki iznosi naknada za korištenje mreža znače ne samo visoke troškove za korisnike mreža, nego, pogotovo za one izvan dosadašnjih integriranih nacionalnih elektroenergetskih sustava, i značajnu prepreku za ulazak na tržište električne energije, a time i njegovom razvoju. Iskazani neopravdano visoki iznosi profita u monopolnim djelatnostima imaju i daljnje negativne političke i socijalne posljedice, čak,

and the adequate development of the regulated energy entities, especially the large network infrastructure systems for the transmission and distribution of electricity. The general goal is, of course, a secure supply of electricity at a realistic, i.e. justified, cost.

7) The regulatory agencies have an important role in the process of the authorization and supervision of the implementation of the plans for the development of the regulated entities, i.e. the transmission and distribution networks and systems, and a supervisory role over the quality and security of the services and functions performed by these energy entities, as well as supply to the end users and users in general. The approaches and practices in various countries differ.

There are regulatory agencies that are deeply involved in and responsible for all the phases and elements of planning (the authorization and supervision of plan implementation), obtaining funds through charges and the incentive elements of these charges (capital expenditures, return on equity) and the general supervisory process of the operations of a regulated entity. On the other hand, initially the roles of some of the regulatory agencies were not characterized by deep involvement. Instead of in-depth regulatory supervision, there were general approaches according to which, for example, planned investments from development and construction plans were approved up to a specified level and as such included in the charges for network use. There are examples of less involvement by a regulatory agency during the initial phases of the introduction of regulation or during the initial regulatory periods. However, as the processes progressed and the regulatory agencies became increasingly involved in an increasing number of cases, in many cases the charges for network use dropped.

8) This nearly completely corresponds with the introduction of more complex regulatory approaches and methodologies of economic regulation, i.e. methods of the incentive regulation of activities. From the aforementioned, it was concluded that at the beginning it is necessary to define the responsibilities of the regulatory agency and the regulated entities as precisely as possible. Furthermore, under the newly arisen market circumstances, it is necessary to include and explain all the important parameters, influential values and market environment circumstances that are being introduced. It is especially important to start with simple regulatory approaches and methods and, as a rule, with short regulatory periods. Any of the potential uncertainties or hidden flaws in a regulatory approach, an incorrectly estimated influential parameter or a target economic index, the unforeseen negative consequences of the restructuring process in a dynamic market environment, or the ultimate consequences of any wrong decisions by the regulatory agency may lead either

ili naročito u slučajevima kada su državna tijela te profite oduzela energetskim subjektima. S druge strane, niski ili nedovoljno visoki iznosi naknada za korištenje mreža direktno ugrožavaju poslovanje energetskih subjekata, kvalitetu usluga i funkcija koje ti subjekti pružaju, a ako takvo stanje traje duže, onda i tehničko-tehnološke osobine same mreže i sustava.

Konačan zaključak u pogledu prethodnog bio je da bez obzira na uzroke, svaki problem i svaka posljedica prenosi se na korisnika ili krajnjeg kupca i postaju njegov problem, a obveza je i energetskog subjekta i regulatornog tijela da u reguliranom okružju te probleme i posljedice otklone. Najefikasnijim općim pristupom otklanjanja svih negativnih posljedica ocjenjuje se pragmatični pristup i postupanje, a ako je moguće i suradnja sve tri zainteresirane strane.

9) Poseban problem i izazov predstavlja regulacija mrežnih infrastrukturnih monopola, prijenosa i distribucije, te u svezi s tim usko povezani problem gdje i pod kojim uvjetima se osiguravaju pomoćne usluge sustava. Naročito se u segmentu pomoćnih usluga sustava mogu pojaviti dominantne pozicije i zlouporabe u još uvijek značajno integriranim sustavima, kada se poduzećima iz sustava ili grupe osiguravaju povoljniji uvjeti pristupa i korištenja pomoćnih usluga ili njihova plaćanja. U sprječavanju takvih situacija, štoviše njihova sankcioniranja, presudna je uloga regulatornih tijela.

Problem pomoćnih usluga i odgovornosti za njihovo osiguranje i pružanje usko je vezan s postojećim zakonodavnim i regulatornim okvirom, ili općenito pitanjem da li se na taj segment primjenjuje regulirani ili tržišni kontekst. U svakom slučaju, u svezi s tim segmentom najviše je pitanja i dilema. Pitanje je i kojoj djelatnosti iz dosadašnje integrirane strukture i jedinstvene tarife koja je uključivala sve djelatnosti i usluge pridijeliti odgovornost za osiguranje pomoćnih usluga, i kako te usluge naplatiti, kao dio odgovarajućih naknada ili zasebno. Neke zemlje taj problem razriješile su pridjeljujući obveze i funkcije osiguranja pomoćnih usluga operatorima prijenosnih i distribucijskih sustava, odnosno uvodeći ugovorne odnose po kojima tržišni sudionici i te usluge slobodno ugovaraju, osiguravaju i na kraju plaćaju. No, istaknuto je, da su takva rješenja i mehanizmi bili moguće tek nakon što je uspostavljena cjelovita funkcionalna i provedbena shema osiguravanja, tj. izvora i pridjeljivanja svake pojedinačne pomoćne usluge ili njene komponente, ali i uvjeta njihova eventualnog prekida i posljedica toga prekida. Činjenica je da su u nekim zemljama, a radi se o zemljama i energetskim gospodarstvima koja su u pravilu u ranim fazama procesa restrukturiranja, otvaranja

to very high or inadmissibly low charges for network use. High charges for network use would not only mean high costs for network users but would also pose a significant barrier to entry into the electricity market and development by those entities outside the current integrated national power systems. The unreasonably high profits of monopolies have further negative political and social consequences, even or especially in cases when government agencies have redirected these earnings away from the entities. On the other hand, low or insufficient charges for network use directly jeopardize the operations of entities, the quality of the services and functions provided by these entities and, if such conditions persist for extended periods, they may also jeopardize the technical and technological characteristics of the network and system.

The final conclusion in respect to the above is that regardless of the cause, each problem and consequence is shifted to the user or the final customers and becomes their problem. Both the entity and the regulatory agency should resolve these issues within the regulated environment and eliminate the consequences. The most efficient general approach to eliminating all such negative consequences is thought to be a pragmatic one, together with cooperation among all three interested parties, if possible.

9) A separate problem and challenge is the regulation of the network infrastructure monopolies, transmission and distribution and, closely connected to this, the issue of where and under which circumstances auxiliary system services should be provided. Especially in the segment of auxiliary services of the system, dominant positions and abuses may occur in systems that are still significantly integrated when enterprises from the system or groups are provided with more favorable conditions for accessing, using or paying for auxiliary services. In order to prevent such situations, moreover to penalize them, the role of the regulatory agencies is crucial.

The issue of auxiliary services and the responsibility for providing them are closely connected to the existing legislative and regulatory frameworks or, in general, to the question whether the regulated or market context should be applied to this segment. In any case, the most questions and dilemmas are associated with this segment. It is a question as to which activities from the current integrated structure and single tariff that included all the activities and services should be assigned responsibility for securing auxiliary services, and how should these services be charged, as a part of the corresponding charges or separately. Some countries have resolved this problem by assigning the obligations and functions for securing auxiliary services to the transmission and distribution system operators, or by introduc-

tržišta, odnosno razvoja i uspostave odgovarajućeg regulatornog okružja, pitanja i problemi uspostave cjelovitog sustava osiguravanja, korištenja, pridjeljivanja i plaćanja pomoćnih usluga sustava još uvijek samo naznačeni ili tek u ranim fazama rješavanja. U svakom slučaju neriješena pitanja i problemi u svezi s pomoćnim uslugama sustava znatno otežavaju razvidnost i efikasnost procesa otvaranja tržišta električne energije u svim njegovim ključnim sastavnicama, a naročito u pogledu osiguranja uvjeta za razvidan, nepristran i pravedan pristup mrežama i sustavima. Takvo stanje ima daljnje negativne posljedice po razvoj i uvođenje novih metoda regulacije i metodologija tarifnih sustava, što posljedično i regulatorno tijelo dovodi u puno teži položaj i ugrožava njegovu vjerodostojnost suočavajući ga s objektivno teškim problemom izbora pristupa i metodologije, ali i reakcijom energetskih subjekata i tržišnih sudionika.

U pravilu, stav je da u reguliranom kontekstu osiguranje i pružanje tih usluga treba biti jedna od funkcija i obveza operatora prijenosnog i distribucijskog sustava, koja je po unaprijed poznatim uvjetima, na razvidan, nepristran i nediskriminirajući način dostupna i pridjeljuje se korisnicima elektroenergetskih mreža i sustava. Zaključak je da razina cijena, odnosno tarifa za pomoćne usluge sustava treba biti troškovno utemeljena i razvidna u svim njegovim elementima. Tijekom rasprave istaknuto je da postoji i problem osiguranja određenih pomoćnih usluga od strane starih proizvodnih postrojenja. Kod postavljanja tržišnog modela o tom se mora voditi računa, naročito kod tržišnih modela koji podrazumijevaju mogućnost pristupa pojedinačnih proizvodnih postrojenja tržištu i njihove participacije na tržištu kao samostalnih tržišnih sudionika. Regulatorna tijela i operatori sustava o tim pitanjima i problemima moraju voditi računa u svim segmentima procesa definiranja tržišnog modela, regulatornog okvira i modela, provedbenih procedura, a ako je kontekst pomoćnih usluga sustava regulirani, onda i metodologiji utvrđivanja tarifnih stavki i proceduri ugovaranja i osiguravanja pomoćnih usluga sustava.

10) Ključnim ciljevima regulacije energetskih djelatnosti, naročito prijenosa i distribucije električne energije smatraju se uspostava nepristranog i razvidnog pristupa mreži, pokriće opravdanih troškova poslovanja, nastojanja da se unaprijedi efikasnost sektora i/ili da se sektor učini privlačnim za nove investicije, odnosno ulaganja. Odgovarajući izvori financiranja mogu se osigurati bilo neposredno kroz naknade za priključak i korištenje mreža, bilo kroz odgovarajuće poticajne uvjete i povrate na investicije, odnosno od i imovinu energetskog subjekta. Postupke i

ing contractual relations on the basis of which the market participants freely contract, provide and at the end pay for these services. However, it has been pointed out that such solutions and mechanisms are only possible after the entire functional and implementation scheme is established, i.e. the source and assignment of each individual auxiliary service or component thereof, as well as the conditions for their eventual termination and the consequences of such termination. The fact is that in some countries, mainly countries and electrical energy economies which are in the early phases of restructuring, market opening and developing an appropriate regulatory environment, the issues and problems of the establishment of the overall system for the provision, use, allocation and payment of auxiliary services are still only on paper or in the early phases of solution. In any case, the unresolved issues and problems in connection with auxiliary system services significantly diminish the transparency and efficiency of the opening of electricity markets in all the key elements, especially regarding the providing of the conditions for the transparent, nondiscriminatory and fair access to networks and systems. Such a situation has further negative consequences upon the development and introduction of new regulatory methods and methodologies of the tariff systems, which consequently place the regulatory agency in a far more difficult position and threaten its credibility, confronting it with the difficult problem of choosing an approach and methodology, as well as the reactions of the entities and market participants.

In principle, the position is that in the regulated context, providing these services should be one of the functions and obligations of the transmission and distribution system operators, which, under predetermined conditions should be available and assigned to users of electricity networks and systems in a transparent, nondiscriminatory and non-discriminatory manner. The conclusion is that the level of prices, i.e. tariffs for the auxiliary services of a system, should be cost-based and transparent in all elements. During the discussion, it was emphasized that there is also the problem of securing certain auxiliary services from the old power-generation facilities. When setting up a market model, this must be taken into account, especially with market models that include the option of access by individual power-generation facilities to the market, and their status as independent market participants. The regulatory agencies and system operators must take these issues and questions into account in all the segments of the process of the definition of a market model, regulatory framework and model, and implementation procedures. If the context of auxiliary system services is regulated, this also means taking into account the methodology for establishing tariff items and procedures for the contracting and providing of auxiliary system services.

metode regulacije i metodologije tarifnih sustava u tom pogledu nužno je stalno dograđivati i unaprjeđivati. U tom pogledu, regulatorno tijelo ima primarni zadatak, ali s obzirom na to da opskrba električnom energijom ostaje i nadalje aktivnost visokog socijalnog i gospodarskog značenja, u rad na predmetnoj problematici trebaju biti uključena poduzeća iz energetskog sektora, tijela državne uprave i druge državne institucije, stručna i ostala javnost, te organizacije za zaštitu interesa potrošača, sindikati i financijske institucije. Sve više je dokaza u prilog opće važnosti koje predmetnoj problematici posvećuju sve navedene stranke.

**11)** Regulatorno tijelo treba imati kontrolu nad svim segmentima regulacijskog razdoblja. Naročito se to odnosi na pripremno razdoblje u kojem bi regulatorno tijelo trebalo biti aktivno uključeno, uz regulirani subjekt. Odnosi se to na pregled ulaznih podataka, podloga i parametara koje se koriste, njihovu obradu, kao i rokove u kojima se pojedini segment pripremne faze za uvođenje metode regulacije mora provesti. U prilog tome govore i odgovarajuća iskustva nekih zemalja.

**12)** U prethodnom kontekstu, u socijalnom, političkom i gospodarskom smislu u svezi sa stabilnošću i sigurnošću opskrbe svakako je dobro izbjegavati velike i nagle skokove u promjenama cijena, nepredvidive ili nenajavljene promjene cijena. U pogledu mogućnosti reguliranih energetskih subjekata da razumiju, prilagode se i provedu odgovarajući regulatorni pristup i prilagode poslovanje novom sadržaju koji su iskazani kroz postupke i metode regulacije, svakako je nužna suradnja regulatornog tijela i reguliranih subjekata. Suradnja je i ključni preduvjet potpunog razumijevanja procesa i sadržaja definicije i uspostave određenog okvira i postupka regulacije, i kroz proces utvrđivanja i donošenja odgovarajućih tarifnih stavki, a time i njihova prihvaćanja i dobre provedbe. Uzimajući u obzir i sve druge moguće utjecaje, npr. socijalni i/ili politički, nije naodmet ustvrditi da se nerijetko postupa pragmatično, nastojeći odvagnuti i nastojeći valorizirati doprinos svakog od tih mogućih utjecaja ili ograničavajućih elemenata.

Od regulatornih tijela traži se kvalitetan i efikasan sustav nadzora nad tržištem električne energije, pogotovo sprječavanje ili čak sankcioniranje situacija u kojima se u tzv. integriranim sustavima sredstva prelijevaju iz monopolnih djelatnosti u tržišne djelatnosti, osiguravajući tržišnim djelatnostima znatnu neopravdanu i neprihvatljivu prednost u odnosu na druge tržišne sudionike u tržišnoj utakmici, što je ujedno i direktan oblik zlouporaba neopravdane tržišne pozicije ili snage. Navedeni su i konkretni slučajevi u kojima su u takvim si-

**10)** The key goals of the regulation of energy activities, especially the transmission and distribution of electricity, are to establish nondiscriminatory and transparent access to the network, cover justified operational costs, attempt to improve the efficiency of the sector and/or make the sector attractive for new investments. Suitable sources of financing can be secured either directly through charges for connection to the network, network use or through suitable incentive conditions and returns on investments, i.e. from the assets of the entities. Procedures and methods for the regulation and methodology of the tariff systems must be constantly updated and improved. In this regard, the regulatory agency has the primary task. However, since the supplying of electricity continues to remain an activity of great social and economic significance, enterprises from the energy sector, government administrative agencies, other government institutions, professionals, the general public, organizations for protecting consumer interests, unions and financial institutions should be included in working on this issue. There is increasing evidence of the general importance afforded to this issue by all the aforementioned parties.

**11)** The regulatory agency must have control over all the segments of the regulatory period. This especially refers to the preparatory period in which the regulatory agency should be actively involved, together with the regulated entity. It concerns a review and processing of the input data, bases and parameters used as well as the periods within which the separate segments of the preparatory phase for the implementation of a regulatory method must be completed. The corresponding experiences of some countries underscore this point.

**12)** In the aforementioned context, in the social, political and economic sense, regarding the stability and safety of supply, it is indeed good to avoid large and sudden price changes and unforeseen or unannounced price changes. Regarding the abilities of the regulated energy entities to understand, adapt to and implement the suitable regulatory approach and adjust operations to the new content expressed through the regulatory procedures and methods, cooperation between the regulatory agency and the regulated entities is certainly essential. Cooperation is also a key prerequisite for completely understanding the process and the contents of the definitions and the establishment of certain frameworks and regulatory procedures, both through the process of the determination and adoption of certain tariff items, and through their acceptance and correct implementation. Taking into account any other possible influences, e.g. social and/or political, it is worth mentioning that a pragmatic approach, in which it is attempted to weigh and evaluate the contribution of each of these potential influences or limiting elements, is often employed.

tuacijama regulatorna tijela postupala tako da se umanjila, ili čak oduzela odgovarajući dio prihoda od integriranog poduzeća, i to od segmenta tržišnih djelatnosti, i vratila ga u segment monopolnih, odnosno djelatnosti s obvezama javnih usluga iz kojeg su i bili neopravdano uzeti. U svakom slučaju, dok postoje dvije paralelne komponente tržišta, regulirana i liberalizirana, odnosno tržišna, regulatorno tijelo ima striktnu obvezu provjeravati razvidnost odvajanja pripadajućih računa i prihoda, a nerijetko i pravo da određene oblike ponašanja i prekršaja i jače sankcionira. Čest je slučaj da regulatorno tijelo ima pravo, utemeljeno na zakonu, samo provesti odgovarajući revizorski nadzor, ili taj nadzor zatražiti od nezavisnih revizora.

13) Okrugli stol je raspravio i pitanja strukture naknada za korištenje prijenosne, odnosno distribucijske mreže. Istaknuta je važnost primjene principa da struktura i razina naknada za korištenje mreža odražavaju strukturu troškova za elemente energije i snage, tj. kapaciteta, prema i za koje se utvrđuju. Poglavito je element snage i njegovo vrednovanje važan u strukturi tarifnih stavki, tj. naknada za priključak, za korištenje prijenosne i distribucijske mreže, i naknada za pomoćne usluge sustava. Važnost elementa kapaciteta ogleda se i u vrednovanju u svezi s mehanizmima pridjeljivanjem, korištenjem i plaćanjem odgovarajućih prekograničnih kapaciteta, ili utvrđivanjem odgovornosti, odnosno postupcima rješavanja zagušenja u prijenosnoj i distribucijskoj mreži.

14) U nekim zemljama proces uvođenja novog regulatornog pristupa i primjene novih metodologija ekonomske regulacije koji u pravilu uključuju parametre valorizacije i poticanja učinkovitosti poslovanja reguliranog energetskog subjekta, a nerijetko i odgovarajuće opće makroekonomske indekse za valorizaciju i pokriće adekvatnih rizika poslovanja i ulaganja, rezultirao je u smanjenju naknada za korištenje mreža. Međutim, nije realno očekivati da bi se takav kontekst ponovio u većini drugih zemalja, pogotovo ne u zemljama u kojima su cijene električne energije bile pod jakom socijalnom i političkom kontrolom i u pravilu vrlo niske. Štoviše, u tim zemljama izražena je potreba za novim velikim ulaganjima u održavanje, rekonstrukciju i izgradnju mreža. Razdvajanje i izdvajanje energetskih djelatnosti iz dosadašnjih vertikalno integriranih elektroenergetskih struktura proizvodnje, prijenosa, distribucije i opskrbe električnom energijom, otvaranje tržišta električne energije i pojava novih sudionika na tržištu električne energije, tu potrebu samo su još više naglasili. Nije rijedak slučaj sve češće iskazanih uvjerenja da bez dobrih i efikasnih infrastrukturnih prijenosnih i distribucijskih mreža i sustava ne može biti govora o razvoju efikasnog tržišta električne energije.

The regulatory agencies are required to provide a quality and efficient system of supervising the electricity market, especially to prevent or penalize situations in which funds flow from monopoly activities into market activities in the so-called integrated systems, which affords businesses with market operations a significant unfair and unacceptable advantage over other market participants in market competition, and is a direct form of the abuse of an inequitable market position or power. Specific cases were mentioned in such situations when the regulatory agencies acted to reduce or even confiscate the corresponding portion of the revenues from an integrated company from the segment of market activities and direct them back to the monopoly segment, i.e. the activities having the public service obligation from which they had been unfairly taken. In any case, as long as there are two parallel components of the market, regulated and liberalized, the regulatory agency has the strict obligation to verify the transparency of the separation of the corresponding invoices and revenues, and not infrequently the right to penalize certain forms of behavior and violations severely. The regulatory agency frequently only has the right, pursuant to the law, to conduct a suitable audit or request to have such an audit performed by independent auditors.

13) The Round Table Discussion also included questions regarding the structure of charges for the use of a transmission or distribution network. The importance was stressed of applying the principle that the structure and level of charges for network use should reflect the structure of the costs of the elements of energy and power, i.e. the capacities according to and for which they are determined. The element of power and its valuation are particularly important for the structure of the tariff items, i.e. charges for connection, the use of the transmission and distribution networks and auxiliary system services. The importance of the capacity elements is reflected in the evaluation in connection with mechanisms for capacity allocation, the use and charges for cross-border capacities, or determination of the responsibilities, i.e. the procedures for managing congestion in the transmission and distribution networks.

14) In some countries, the process of introducing a new regulatory approach and the application of new methodologies of economic regulation, which as a rule include the parameters for the evaluation and increased effectiveness of the operations of a regulated power entity and not infrequently the corresponding general macroeconomic indices for the evaluation and coverage of adequate risk operations and investments, have resulted in lowered charges for network use. However, it is not realistic to expect such a context to be repeated in the majority of other countries, especially those where electricity prices

Na spomenuti kontekst ulaganja u održavanje, rekonstrukciju i izgradnju nacionalnih elektroenergetskih mreža, odnosno izgradnje novih visokonaponskih prijenosnih prekograničnih poveznica s drugim zemljama i sustavima sve važniji utjecaj ima regionalni i širi multinacionalni kontekst tržišta i razmjena električne energije. Opća je pojava da prekogranična trgovanja i razmjene energije vrlo brzo rastu, zbog čega su za tranzite i prekogranične razmjene energije uvedeni i primjenjuju se novi opće prihvaćeni kompenzacijski i alokacijski mehanizmi. Isti se već jednoznačno primjenjuju u kontekstu internog europskog tržišta električne energije. Nadalje, prihodi ostvareni prekograničnim razmjenama moraju se tretirati na razvidan i nepristran način. Međutim, unatoč nastojanju da se razvije i uspostavi efikasan, razvidan, nepristran i pravedan, u konačnici i lako provediv sustav i mehanizam, za neke elektroenergetske sustave i nadalje ostaje problem načina utvrđivanja i alokacije troškova za visoke gubitke električne energije. Isto vrijedi i u pogledu adekvatnog dijela pomoćnih usluga sustava. Naime, radi se o onom dijelu dodatnih gubitaka električne energije u nacionalnoj elektroenergetskoj mreži i dijelu dodatnih pomoćnih usluga sustava koji nastaju zbog prolaza ili kružnih tokova energije iz međunarodnih, tj. prekograničnih razmjena energije. Opći je stav da europsko energetsko zakonodavstvo, tj. odgovarajuće direktive i uredbe EU u tom pogledu predstavljaju adekvatan zakonodavni okvir za postupanje svih regulatornih tijela.

**15)** Poseban je problem načina pristupa i dobivanja informacija i podatak koje s jedne strane regulatorno tijelo može tražiti i traži od reguliranih subjekata, a koje s druge strane ti regulirani subjekti mogu i žele dati ili daju regulatornom tijelu. U svakom slučaju razlike, tj, asimetrija informacija, u tom pogledu uvijek su prisutne. Zaključak je da je u svakom slučaju, bilo u pogledu zadovoljavajućeg rješenja, bilo barem dobre ravnoteže između regulatornog tijela i reguliranih energetskih subjekata najbolje i najefikasnije odabrati pragmatična rješenja, po mogućnosti zasnovana na dostupnoj najboljoj i najefikasnijoj međunarodnoj praksi i benchmarku. Prethodno gotovo u potpunosti vrijedi i u pogledu procesa i prakse regulatornog ili revizorskog nadzora.

**16)** Posebno je uočena i istaknuta mogućnost i potreba šire, tj. regionalne elaboracije i rasprave problema sadržaja i forme regulacije, regulatornih pristupa i politike, strukture i sadržaja tarifnih metodologija i samih tarifa, utjecajnih parametara i pokazatelja, naročito ekonomskih i političkih, usporednih *(benchmark)* pristupa i analiza, te svakako veće suradnje i transfera znanja i iskustava.

have been under rigorous social and political control and, as a rule, very low. Moreover, in these countries there is a marked need for major new investments in maintenance, reconstruction and network construction. The separation of energy activities from the heretofore vertically integrated structures of the generation, transmission, distribution and supply of electricity, the opening of the electricity markets and the appearance of new participants on the electricity market further underscore this need. Opinions are frequently voiced that the development of an efficient electricity market is not feasible without a good and efficient infrastructure for the transmission and distribution networks and systems.

In this context, investments in the maintenance, reconstruction and construction of national electrical energy networks or in the construction of new high voltage transmission cross-border connections with other countries and systems have an increasing impact upon the regional and broader multinational context of the markets and the exchange of electricity. The cross-border commerce and exchange of energy is generally growing very rapidly, due to which new commonly accepted compensation and allocation mechanisms have been introduced and applied for the transit and cross-border exchange of energy. Such mechanisms are already being applied uniformly within the context of the internal European electricity market. Furthermore, the revenues from cross-border exchanges must be treated in a transparent and nondiscriminatory manner. However, despite attempts to develop and establish an efficient, transparent, nondiscriminatory, just and, in the final analysis, easily applicable system and mechanism, some energy systems are still confronted with the problem of how to determine and allocate expenditures for high losses of electricity. This concerns the share of the additional electricity losses in the national electrical energy network and the share of the additional auxiliary system services that occur due to transit or circular flows from international, i.e. cross-border, energy exchanges. The general position is that the European energy legislation, i.e. the corresponding directives and regulations of the EU in this respect, represents an adequate legislative framework for the operations of all the regulatory agencies.

**15)** There is a specific problem regarding the manner of accessing and obtaining information and data which a regulatory agency can and does require from regulated entities, and which these regulated entities can and want to provide or do provide to the regulatory agency. In any case, these differences, i.e. information asymmetry, are always present in this regard. The conclusion is that in order to obtain a satisfactory solution or at least a good balance between the regulatory agency and the regulated en-

# 5 ZAKLJUČAK

Okrugli stol o ulozi regulatornog tijela u donošenju tarifnih sustava organiziran je kao mjesto susreta i rasprave eksperata i direktnih sudionika, odnosno zainteresiranih strana u regulacijskom procesu, od predstavnika regulatornih tijela, stručne i znanstvene javnosti, do predstavnika reguliranih subjekata. Okrugli stol bio je vrlo uspješan i u potpunosti je opravdao razloge organiziranja, ponudivši dobru elaboraciju problematike i sadržaja regulacije energetskih djelatnosti, organizacije i nadzora tržišta električnom energijom, a posebno i ciljano uloge regulatornog tijela u donošenju tarifnih sustava. Konačno, Okrugli stol ponudio je i niz odgovora, ali i što je još važnije, sudionike je ili uveo u predmetnu problematiku i ukazao im na opću prisutnost sličnih pitanja i dilema u svim zemljama, od članica EU do zemalja koje će tek postati članice EU, ili im dao odgovore na pitanja i dileme s kojima su došli na Okrugli stol. Bez obzira na različita iskustva i dinamiku procesa, Okrugli stol je pomogao da se identificira i komentira niz izazova i problema s kojima se suočavaju sva regulatorna tijela, ali i sva regulirana poduzeća i energetski subjekti, bez obzira na sustave iz kojih dolaze i kontekst u kojem su nastala i u kojem su se razvijala. Također, uočena je mogućnost i potreba za stalnom elaboracijom i raspravom problema sadržaja i forme regulacije, regulatornih pristupa i politike, strukture i sadržaja tarifnih metodologija i samih tarifa, utjecajnih parametara i pokazatelja, naročito ekonomskih i političkih, usporednih *(benchmark)* pristupa i analiza, te svakako veće suradnje i transfera znanja i iskustava.

Zbog svega prethodnog, cilj i svrha ovog članak bili su širu stručnu i znanstvenu javnost izvijestiti o rezultatima, odnosno tijeku i zaključcima tog Okruglog stola, te eventualno potaći stručnu i znanstvenu raspravu o izloženoj problematici, pa čak potaći organizaciju novih okruglih stolova i rasprava o izloženim pitanjima, problemima, sadržajima, ali i izazovima regulacije energetskih djelatnosti.

ergy entities, it is best and most efficient to choose pragmatic solutions, if possible based upon the best available and most efficient international practices and benchmarks. The aforementioned applies in its entirety to the processes and practices of regulatory or audit supervision.

16) We have especially noted and emphasized the possibility and necessity for the broader regional elaboration and discussion of the problems of the contents and forms of regulations, regulatory approaches and policies, the structures and contents of tariff methodologies and the tariffs themselves, influential parameters and indices (especially economic and political), benchmark approaches and analysis, together with greater cooperation and the transfer of knowledge and experiences.

# 5 CONCLUSION

The Round Table Discussion on the role of the regulatory agency in the adoption of tariff systems was organized as place of meeting and discussion among experts and direct participants, i.e. interested parties in the regulatory process, from representatives of the regulatory agencies, the professional and scientific public, to representatives of the regulated entities. The Round Table was highly successful and completely justified the reasons for its organization, providing good elaboration of the issues and contents of the regulations on energy operations, the organization and supervision of the electricity market and, particularly, the planned role for the regulatory agency in the adoption of the tariff systems. Finally, the Round Table Discussion provided a series of answers but, more importantly, introduced the participants to the issue under discussion and demonstrated to them that similar questions and dilemmas are generally present in all countries, from the member countries of the EU to the countries that will become members of the EU, or provided them with answers to the questions and dilemmas that they brought with them to the Round Table. Regardless of the various experiences and process dynamics, the Round Table Discussion helped identify and comment on a series of challenges and problems confronted by all regulatory agencies, as well as all regulated enterprises and energy entities, regardless of the systems from which they come and the context in which they originated and developed. Furthermore, the possibility and need were perceived for the ongoing elaboration and discussion of the problems of the content and form of regulation, regulatory approaches and policies, the structure and content of tariff methodologies and the tariffs themselves, the influential parameters and indices (especially economic and political), benchmark approaches and analysis, and certainly

greater cooperation and the transfer of knowledge and experience.

Due to all the aforementioned, the goal and purpose of this article were to inform the general professional and scientific public about the results and conclusions of this Round Table Discussion, eventually stimulate expert and scientific discussion about the issues presented, and even stimulate the organization of new round tables and discussions on the questions, problems, contents but also the challenges of the regulation of energy operations.

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Uredništvo primilo rukopis:
2007-07-30

Prihvaćeno:
2007-08-13

Manuscript received on:
2007-07-30

Accepted on:
2007-08-13

# REGULATORNA POLITIKA I NJEN UTJECAJ NA PLANOVE RAZVOJA I IZGRADNJE ENERGETSKIH SUBJEKATA KOJI OBAVLJAJU REGULIRANE DJELATNOSTI

# REGULATORY POLICY AND ITS IMPACT ON THE DEVELOPMENT AND CONSTRUCTION PLANS OF ENTITIES PERFORMING REGULATED ACTIVITIES

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Hrvatska energetska regulatorna agencija u prosincu 2006. godine donijela je tarifne sustave bez visine tarifnih stavki za djelatnosti proizvodnje, prijenosa, distribucije i opskrbe električnom energijom. Tarifnim sustavima utvrđena je metoda regulacije koja će se primjenjivati prilikom utvrđivanja iznosa tarifnih stavki za pojedinu djelatnost. Jedan od preduvjeta za donošenje iznosa tarifnih stavki od strane Vlade Republike Hrvatske je donošenje planova razvoja i izgradnje prijenosne i distribucijske mreže od strane energetskih subjekata koji obavljaju regulirane djelatnosti na koje Hrvatska energetska regulatorna agencija daje suglasnost.

In December 2006, the Croatian Energy Regulatory Agency – CERA (Hrvatska energetska regulatorna agencija – HERA) adopted tariff systems without stipulating the amounts of the tariff items for the activities of the generation, transmission, distribution and supply of electrical energy. A regulatory method was established through the tariff systems that will be applied in the determination of the amounts of the tariff items for individual activities. One of the prerequisites for the adoption of the amounts of tariff items by the Government of the Republic of Croatia is the adoption of the development and construction plans of the transmission and distribution networks to which the CERA issues approval.

Ključne riječi: planovi razvoja, regulatorna politika, regulatorno tijelo, regulirani energetski subjekt, tarifni sustavi

Key words: development plans, entity performing regulated activity, regulatory body, regulatory policy, tariff systems

# 1 UVOD

U prosincu 2006. godine Hrvatska energetska regulatorna agencija (HERA) donijela je tarifne sustave, bez visine tarifnih stavki za četiri djelatnosti čija se cijena utvrđuje na regulirani način [1]:

– proizvodnju električne energije s iznimkom povlaštenih kupaca,
– prijenos električne energije,
– distribuciju električne energije,
– opskrbu električnom energijom s iznimkom povlaštenih kupaca.

U navedenim tarifnim sustavima definirana je i regulatorna politika, odnosno metoda ekonomske regulacije, a to je metoda priznatih troškova poslovanja [2] do [5]. U teoretskim razmatranjima regulacije energetskih djelatnosti ova metoda svrstana je u klasični pristup regulaciji poznat i pod nazivom regulacija stopom povrata [6]. Tu metodu regulatorna tijela u državama članicama Europske unije (EU) sve više napuštaju i zamjenjuju metodama poticajne regulacije u kombinaciji s regulacijom kvalitete opskrbe [7], budući da se pokazalo da primjena regulacije stopom povrata potiče podizanje troškova ulaganja iznad onih koje bi subjekti koji obavljaju reguliranu djelatnost snosili da ulažu po kriteriju minimalnih troškova. Pokazalo se da u načelu regulacija stopom povrata postiže suprotan učinak od onog kojeg bi trebala osigurati ekonomska regulacija kroz nezavisno regulatorno tijelo. Ciljevi ekonomske regulacije prvenstveno su [7]:

– poticanje učinkovitosti i povećanje produktivnosti,
– osiguranje primjerene financijske sposobnosti sektora,
– sprječavanje diskriminacije kupaca i energetskih subjekata.

Regulatorna politika prema ulaganjima subjekata koji obavljaju regulirane djelatnosti jedan je od ključnih segmenata u provođenju ekonomske regulacije. Nova ulaganja, ako su prihvaćena kao dozvoljeni trošak, uključena su u regulatornu osnovicu sredstava, kroz amortizaciju i iznos dozvoljenog povrata sredstava. Regulatorno tijelo može imati značajnu ulogu u utvrđivanju opravdane razine ulaganja, a time i u postupku utvrđivanja cijene reguliranih djelatnosti. Tim više, ako se uzme u obzir činjenica da mnoga zakonska rješenja predviđaju da regulatorno tijelo daje suglasnost ili donosi planove razvoja subjekata koji obavljaju regulirane djelatnosti.

# 1 INTRODUCTION

In December 2006, the Croatian Energy Regulatory Agency (CERA) adopted tariff systems without stipulating the amounts of the tariff items for four activities for which the prices are determined in a regulated manner [1]:

– the generation of electrical energy, with the exception of eligible customers,
– the transmission of electrical energy,
– the distribution of electrical energy,
– the supply of electrical energy, with the exception of eligible customers.

In these tariff systems, the regulatory policy, i.e. the method of economic regulation, was defined [2] to [5]. In theoretical studies of the regulation of energy activities, this method is classified in the classical approach to regulation that is known as the rate of return (*RoR*) method [6]. This method is being increasingly abandoned by the regulatory bodies in the member countries of the European Union (EU) in favor of incentive regulation methods in combination with regulation of the quality of supply [7], since it has become evident that application of the regulation of the rate of return raises investment costs above those that entities performing regulated activities would otherwise have to pay if they invested according to the criterion of minimal costs. Furthermore, it has become evident that in principle the regulation of the rate of return achieves the opposite effect to that which should be assured by economic regulation through an independent regulatory body. The goals of economic regulation are primarily as follows [7]:

– promoting efficiency and increasing productivity,
– assuring the appropriate financial viability of the sector,
– preventing discrimination against customers and energy entities.

The regulatory policy toward the investments by entities performing regulated activities is one of the key segments in the implementation of economic regulation. New investments, if accepted as allowed expenditures, are included in the regulatory asset base (*RAB*) through depreciation and the amount of the allowed return on assets. The regulatory body, therefore, can have a significant role in determining the justified level of investment, and thereby in the procedure for the determination of the prices for regulated activities. This is even more the case when the fact is taken into account that many legal solutions anticipate that the regulatory body will issue approval or adopt the development plans of the entities performing regulated activities.

Hrvatska je na početku uvođenja ekonomske regulacije u energetskim djelatnostima, stoga se u ovom trenutku još ne mogu analizirati učinci regulatorne politike u cijelosti kao niti pojedinih regulatornih odluka. Iako su tarifni sustavi, bez visine tarifnih stavki, doneseni u prosincu 2006. godine, koliko je poznato autorima (u vrijeme predaje ovog članka uredništvu) procedura donošenja iznosa tarifnih stavki nije još započela. Za donošenje iznosa tarifnih stavki potrebno je prije svega da energetski subjekti HEP Operator prijenosnog sustava d.o.o. (HEP OPS) i HEP Operator distribucijskog sustava d.o.o. (HEP ODS) dostave HERA-i na suglasnost prijedlog trogodišnjih planova razvoja i izgradnje, a sve temeljem Zakona o tržištu električne energije [8].

Kod razmatranja planova razvoja i izgradnje prijenosne i distribucijske mreže, nameće se pitanje koje se odnosi na dubinu nadležnosti regulatornog tijela, pa tako i HERA-e, odnosno na njegovu poziciju u odnosu na davanje suglasnosti na pojedina koncepcijska rješenja, odnosno na pojedina tehnička pitanja. Naime, temeljem Zakona o tržištu električne energije [8] HEP OPS i HEP ODS donose planove razvoja i izgradnje mreža za razdoblje od tri godine tek po ishođenoj prethodnoj suglasnosti HERA-e na svoje prijedloge planova. Doneseni planovi ujedno su i ishodište za utvrđivanje iznosa tarifa. Samim zakonskim odredbama nije razvidno definirana dubina uloge HERA-e u smislu njenih ovlasti prilikom davanja tih suglasnosti.

Budući da su iskustva u Hrvatskoj u smislu utjecaja regulatornog tijela na planove razvoja i izgradnje tek u začetku, zanimljivo je analizirati ulogu drugih regulatornih tijela u donošenju planova poslovanja, tj. razvoja i izgradnje subjekata koji obavljaju regulirane djelatnosti. Iskustva regulatornih tijela članica udruženja energetskih regulatornih tijela iz Europe (*Energy Regulators Regional Association* – ERRA) [9], u kojima je regulacija i konkurentno tržište električne energije relativno novi koncept, vrlo su različita u smislu uloge regulatornog tijela u davanju suglasnosti na planove razvoja i izgradnje. U većini slučajeva regulatorna tijela ne utvrđuju kriterije planiranja razvoja prijenosne i distribucijske mreže, niti utječu na koncepcijska i tehnička rješenja koja vrlo često proizlaze iz odluka uprave tvrtki, već se njihova uloga svodi na odobravanje poslovnih planova Operatora prijenosnih sustava (OPS) i Operatora distribucijskih sustava (ODS). Paralelno odobravanju poslovnih planova, regulatorna tijela postupno uvode i razvidne kriterije kvalitete opskrbe kako bi se izbjeglo smanjenje kvalitete opskrbe zbog smanjivanja troškova kroz primjenu regulatorne metode te da bi se ujedno postiglo planiranje razvoja mreže koje za cilj ima

The Republic of Croatia is in the initial phase of introducing economic regulation into energy activities. Therefore, at this moment it is still not possible to analyze the effects of the regulatory policy in their entirety or individual regulatory decisions. For the adoption of the amounts of tariff items, it will be necessary for the HEP Transmission System Operator – HEP TSO (HEP Operator prijesnog sustava d.o.o. – HEP OPS) and the HEP Distribution System Operator – HEP DSO (HEP Operator distribucijskog sustava – HEP ODS) as energy entities to submit their proposed three-year development and construction plans to the CERA for approval, all pursuant to the Electricity Market Act [8].

When considering the development and construction plans of transmission and distribution networks, a question arises in reference to the degree of the authority of the regulatory body, and thus of the CERA, i.e. its position in relation to issuing approval for individual conceptual solutions or individual technical questions. Pursuant to the Electricity Market Act [8], the transmission system operator and the distribution system operator only adopt plans for the development and construction of networks for a period of three years after obtaining prior approval from the CERA for their proposed plans. The adopted plans are also the basis for the determination of the amounts of tariffs. The legal provisions themselves have not transparently defined the range of the CERA's role in the sense of its authority when issuing these approvals.

Since experiences in the Republic of Croatia regarding the influence of the regulatory body on development and construction plans are only in the initial phase, it is interesting to analyze the role of other regulatory bodies in the adoption of business plans, i.e. development and construction by entities performing regulated activities. The experiences of the member regulatory bodies of the Energy Regulators Regional Association (ERRA) [9], in which regulation and a competitive electrical energy market are relatively new concepts, vary considerably in the sense of the role of the regulatory body in issuing approval for development and construction plans. In the majority of cases, the regulatory bodies neither determine the criteria for planning the development of transmission and distribution networks, nor do they influence the conceptual and technical solutions that very often ensue from the decisions of company management, but instead their role is limited to approving the business plans of the transmission system operator and the distribution system operator. Together with the approval of business plans, regulatory bodies are gradually introducing transparent criteria for the quality of supply in order to avoid lowering the quality of the supply due to reduced expenditures through the application of regulatory methods in order to

povećanje učinkovitosti, odnosno povećanje kvalitete opskrbe.

Odabirom metode regulacije priznatih troškova i regulatornog razdoblja od godinu dana unutar kojeg je moguće inicirati izmjene visine tarifnih stavki, HERA nije dala naglasak na povećanje učinkovitosti subjekata koji obavljaju regulirane djelatnosti koji je jedan od glavnih ciljeva ekonomske regulacije. Imajući u vidu iskustva drugih regulatornih tijela iz EU, nužno će u skorašnje vrijeme uslijediti izmjena regulatorne metode, a time će i HERA intenzivnije pristupiti analizi ovisnosti regulatornog pristupa i razine faktora učinkovitosti primjenjujući neku od metoda poticajne regulacije. U članku se analiziraju dva regulatorna pristupa u primjeni faktora učinkovitosti i ulozi regulatornog tijela u odobravanju investicijskih planova subjekata koji obavljaju regulirane djelatnosti poznatih pod nazivom regulatorni pristup slaganja blokova (engl. *Building Blocks Appraoch*) i regulatorni pristup ukupnog troška (engl. *Total Expenditures Approach – TOTEX Approach*). O odabranom regulatornom pristupu ovisi i način na koji regulatorno tijelo ocjenjuje učinkovitost pojedinih ulaganja i razmatra opravdanost razine predviđenih ulaganja.

## 2 PRAKSA U ČLANICAMA ENERGY REGULATORS REGIONAL ASSOCIATION

Zemljopisno gledano ERRA je udruženje regulatornih tijela iz Europe (pojedine države ujedno su i članice EU) i bivših država Sovjetskog saveza osnovano 2000. godine. Trenutačno su u udruženju punopravno učlanjena 22 regulatorna tijela uključujući i HERA-u. Na sastancima odbora ERRA-e raspravlja se i razmjenjuju se iskustva o nadležnostima regulatornih tijela, problemima i izazovima s kojima se susreću regulatorna tijela. Jedna od nadležnosti većine regulatornih tijela je i sudjelovanje u postupku donošenja razvojnih/investicijskih planova energetskih subjekata koji se bave prijenosom i distribucijom električne energije u vidu tehničkih, financijskih ili poslovnih planova. Planovi se donose kao preduvjet za utvrđivanje metodologija za izračun cijena usluga ili donošenje samih iznosa cijena usluga. Pitanja koja se nameću prilikom rasprave o ulozi regulatornih tijela u donošenju predmetnih planova su:

– koliko duboko i detaljno regulatorno tijelo treba biti uključeno u izradu i donošenje razvojnih/investicijskih planova, posebice kada se radi o strateškim dilemama ili tehničkim rješenjima,

achieve the planned development of the network with the goal of improving efficiency, i.e. improving the quality of the supply.

Through the selection of the rate of return (*RoR*) method and a regulatory period of one year within which it is possible to initiate changes in the amounts of the tariff items, the CERA did not place emphasis on increasing the efficiency of the entities performing regulated activities, which is one of the main goals of economic regulation. Bearing in mind the experiences of other regulatory bodies from the EU, changes in the regulatory method will have to follow soon, and the CERA will have to intensify its analysis of the dependence of the regulatory approach and the level of the efficiency factor, applying some incentive regulation method. In this article, two regulatory approaches are analyzed in the application of the efficiency factor and the roles of the regulatory body in the approval of the investment plans of entities performing regulated activities, known as the building block approach, and the regulatory approach known as the total expenditure approach or the *TOTEX* approach. The choice of the regulatory approach will also determine the manner in which the regulatory body will assess the performance of individual investments and analyze the justification for the level of individual investments.

## 2 PRACTICES AMONG THE MEMBERS OF THE ENERGY REGULATORS REGIONAL ASSOCIATION (ERRA)

Viewed geographically, the ERRA is an association of the energy regulatory bodies from Europe (some of the countries are also members of the EU) and the former the Soviet Union, which was established in the year 2000. Currently, there are twenty-two regulatory bodies that are full members, including the CERA. At the meetings of the ERRA committees, experiences are discussed regarding the authorities of the regulatory bodies, together with the problems and challenges encountered by the regulatory bodies. One of the authorities of the majority of the regulatory bodies is participation in the procedure for the adoption of the development/investment plans of the energy entities engaged in the transmission and distribution of electrical energy, regarding technical, financial or business plans. Plans are adopted as a prerequisite for the determination of the methodologies for the calculation of the prices for services or the adoption of the amounts of the prices of the services. Questions posed during the discussions on the role of the regulatory bodies in the adoption of these plans are as follows:

– treba li regulatorno tijelo biti ta instanca koja će utvrditi jedinični trošak pojedine opreme,
– koje sastavne dijelove mora sadržavati svaki razvojni/investicijski plan.

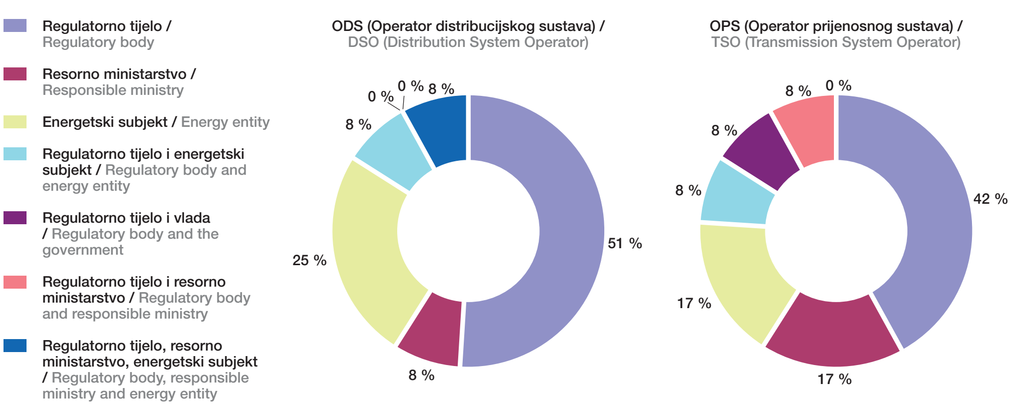
Na ova pitanja i dileme ERRA-in Odbor za tarife i cijene pokušao je u 2005. godini odgovoriti kroz analizu iskustava država članica [9]. Međutim, provedena analiza je pokazala da se uloga regulatornog tijela u donošenju razvojnih/investicijskih planova značajno razlikuje ovisno o zakonskim rješenjima, nadležnostima regulatornih tijela te stručnoj, tehničkoj i financijskoj osposobljenosti regulatornih tijela.

Upitnik koji je tom prilikom pripremljen, analiziran i prezentiran sadrži 33 pitanja. Svoje odgovore na pitanja iz Upitnika dala su regulatorna tijela iz 12 država (Armenija, Bosna i Hercegovina, Bugarska, Hrvatska, Estonija, Gruzija, Latvija, Litva, Makedonija, Poljska, Rumunjska i Ukrajina). U državama koje su odgovorile na Upitnik broj OPS-ova uglavnom je jedan, dok se broj ODS-ova kreće između 1 i više od 200 (Poljska). U većini država regulatorno tijelo daje suglasnost na razvojne/investicijske planove OPS-a i ODS-a (slika 1). Međutim, postoje i rješenja u kojima regulatorno tijelo nije uključeno u proces donošenja planova, već je to npr. u potpunosti u nadležnosti energetskih subjekata. Razdoblje na koje se donose planovi kreće se od jedne do deset godina, kako za OPS tako i za ODS.

– how deep and thorough should a regulatory body's involvement be in the preparation and adoption of development/investment plans, especially regarding strategic dilemmas or technical solutions?
– should the regulatory body be the one to define the unit costs of individual types of equipment?
– what are the integral parts that every development/investment plan should have?

In 2005, the ERRA Tariff/Pricing Committee attempted to answer these questions and dilemmas through analysis of the experiences of the member countries [9]. However, the analysis performed demonstrated that the roles of the regulatory bodies in the adoption of development/investment plans vary significantly, depending upon the legal solutions, the authorities of the regulatory bodies and the professional, technical and financial abilities of the regulatory bodies.

The questionnaire that was prepared, analyzed and presented on this occasion has thirty-three questions. The regulatory bodies from twelve countries (Armenia, Bosnia and Herzegovina, Bulgaria, Croatia, Estonia, Georgia, Latvia, Lithuania, Macedonia, Poland, Rumania and the Ukraine) answered the questions on the questionnaire. In the countries that responded to the questionnaire, the number of TSO (transmission system operators) is generally one, while the number of DSO (distribution system operators) ranges between one and over two hundred (Poland). In the majority of the countries, the regulatory body issues approval for the development/investment plans of the transmission system operators and distribution system operators (Figure 1). However, there are also solutions in which the regulatory body is not included in the process of the adoption of plans but instead, for example, the energy entities have full authorization for this. The periods for which plans are adopted range from one to ten years, for both transmission system operators and distribution system operators.




**Slika 1**
Raspodjela nadležnosti davanja suglasnosti na planove razvoja/investicija ODS-a i OPS-a u članicama ERRA-e (analiza je provedena za 12 država)
**Figure 1**
Distribution of authority for issuing approval for the development/investment plans of distribution system operators and transmission system operators among the members of ERRA. (Analysis was performed for twelve countries)

Pitanja koja su zanimljiva za ulogu regulatornog tijela u donošenju planova posebice se odnose na dubinu regulatornog utjecaja u području:

- tehničkih rješenja, npr. zamjena elektro-mehaničkih digitalnim mjernim uređajima,
- koncepcijskih dilema u razvoju visokonaponske (VN) i srednjonaponske (SN) mreže, kao što je npr. interpolacija SN/SN trafostanica,
- troška građevinskih radova,
- utvrđivanja jediničnih troškova opreme.

Prva dva područja u načelu su u većini država u nadležnosti energetskih subjekata i stvar su odluke OPS-a, odnosno ODS-a. Utvrđivanje troškova za druga dva navedena područja proizlazi iz javnih nabava. Isto tako, kada se analizira tko je nadležan za utvrđivanje kriterija za planiranje prijenosne i distribucijske mreže, proizlazi da su to prvenstveno energetski subjekti, a ne regulatorna tijela (slika 2).

Postavlja se pitanje koja je onda stvarna uloga regulatornih tijela u donošenju planova razvoja/investicija OPS-a/ODS-a, odnosno kakav utjecaj može imati regulatorno tijelo na dinamiku i visinu investicija, kao i na koncepcijska rješenja. Budući da je većina analiziranih regulatornih tijela u načelu tek u početku primjene regulatorne prakse te uspostavljanja kompetentnog i stručno osposobljenog regulatornog tijela, u većini slučajeva regulatorna uloga se svodi na analizu i nadzor financijskih i računovodstvenih izvješća, a ne na utvrđivanje kriterija za tehnička rješenja i odobravanje opravdane visine pojedinih investicija. Kao ilustrativni primjer financijskog, odnosno poslovnog, nadzora može se navesti praksa u pojedinim državama članicama ERRA-e koje su odgovorile na pitanje iz upitnika koje se odnosi na financijske i poslovne kriterije utvrđene za regulatorni nadzor energetskih subjekata.

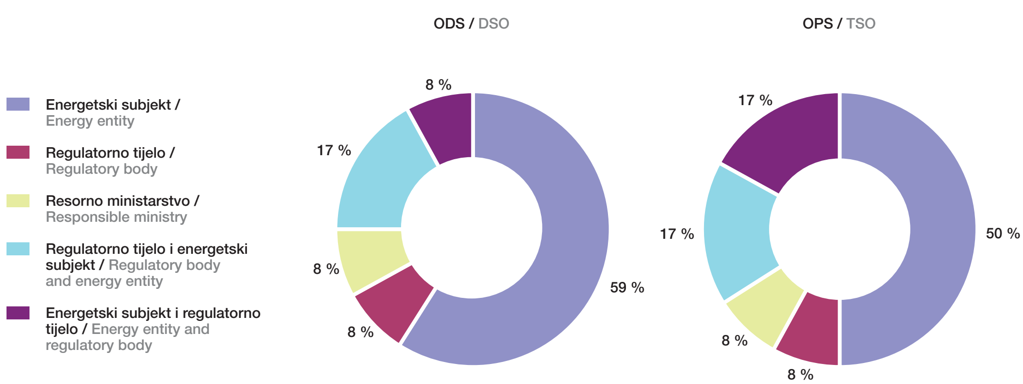
Questions of interest regarding the role of the regulatory body in the adoption of plans particularly refer to the extent of regulatory influence in the following areas:

- technical solutions, e.g. the replacement of electromechanical metering devices with digital ones,
- conceptual dilemmas in the development of high voltage and medium voltage networks, such as, for example, the interpolation of MV/MV substations,
- costs of construction work, and
- the determination of the unit costs of equipment.

In the majority of the countries, the first two areas are in principle under the authority of the energy entities and matters for decision by the transmission system operator or the distribution system operator. The definition of costs for the other two areas mentioned comes from public procurements. Similarly, it is primarily the energy entities and not the regulatory bodies which are authorized to define the criteria for the planning of transmission and distribution networks (Figure 2).

Therefore, the question is posed concerning the actual roles of the regulatory bodies in the adoption of the development/investment plans of transmission system operators and distribution system operators, i.e. what influence can a regulatory body have on the dynamics and amount of investment, as well as on the conceptual solution. Since the majority of the analyzed regulatory bodies in principle are only beginning to apply regulatory practices in the establishment of competent and professionally qualified bodies, in the majority of cases the regulatory role is limited to the analysis and audit of financial and accounting reports, and not the determination of the criteria for the technical solutions and the approval of the justified amounts of individual investments. An illustrative example of financial or operational supervision is the practice in some member countries of the ERRA which responded to the questions on the questionnaire that refer to the financial and operational criteria established for the regulatory supervision of energy entities.

**Slika 2**
Raspodjela nadležnosti za utvrđivanje kriterija za planiranje prijenosne i distribucijske mreže u članicama ERRA-e (analiza je provedena za 12 država)
**Figure 2**
The distribution of authority for the determination of criteria for the planning of transmission and distribution networks among member countries of the ERRA (analysis of 12 countries)



U Bugarskoj se financijski nadzor provodi na temelju odabranih financijskih pokazatelja koji su utvrđeni kao pokazatelji od važnosti za regulatorni nadzor. Analiza ovih pokazatelja trebala bi odgovoriti na pitanje primjenjuju li energetski subjekti mjere utvrđene od strane regulatornog tijela koje za cilj imaju povećanje ekonomske učinkovitosti proizašle iz primjene poticajne regulacije. U Latviji tarifna metodologija utvrđuje način na koji se dostavlja prijedlog tarifa, odnosno utvrđuje set potrebnih podataka koje je potrebno dostaviti regulatornom tijelu. U Ukrajini nadzor poslovnih planova provodi se kroz računovodstveni nadzor i izvješća za potrebe regulatornog tijela. Poslovni, odnosno investicijski planovi između ostalog moraju sadržavati iznos godišnjeg budžeta, izvor financiranja te detaljnu elaboraciju troškova. Za ukrajinsko regulatorno tijelo potrebno je naglasiti da već dugi niz godina primjenjuje razne vrste metoda ravnanja prema mjerilu (engl. *benchmarking*) za koje je podatak o troškovima za pojedinačne investicije više nego dobrodošao.

Odgovori na Upitnik pokazali su da u većini država regulatorno tijelo provodi nadzor nad realizacijom predviđenih investicija tijekom postupka utvrđivanja tarifa za novo regulatorno razdoblje. Ono što je bitno kod utvrđivanja cijena usluga i uključivanja pojedinih troškova u razinu prihoda energetskog subjekta odobrenog od strane regulatornog tijela je realizacija investicija iz investicijskog ciklusa. Naime, ukoliko je pojedina investicija odobrena i uključena u investicijske planove, te su za istu alocirana potrebna sredstva u regulatornom razdoblju, tu istu investiciju ne može se uključiti u regulirani trošak u novom regulatornom razdoblju. Proizlazi da je nadzor regulatornog tijela vrlo bitan u segmentu nadzora nad realizacijom investicijskih planova subjekata koji obavljaju regulirane djelatnosti.

Ukoliko energetski subjekt ne realizira predviđeni investicijski ciklus, u pojedinim državama (Armenija, Latvija, Litva, Poljska, Ukrajina), u sljedećem regulatornom razdoblju dolazi do smanjenja iznosa reguliranih tarifnih stavki. No, moguća su i drastičnija rješenja, kao npr. u Armeniji, gdje regulatorno tijelo osim smanjenja iznosa tarifnih stavki može izreći upozorenje ili oduzeti dozvolu za obavljanje energetske djelatnosti. Međutim, ukoliko se radi o OPS-u, postavlja se pitanje tko će obavljati djelatnost ukoliko se oduzme dozvola. Nadalje, kao sankcija za neispunjavanje investicijskog ciklusa, moguće su i novčane kazne, npr. u Ukrajini do 16 000 američkih dolara. I u hrvatskom zakonu [8] predviđena je novčana kazna za energetski subjekt u iznosu do 50 000 kuna ukoliko ne izrađuje planove razvoja i izgradnje, odnosno ukoliko ih ne

In Bulgaria, financial supervision is performed on the basis of selected financial indices that are determined as indices of importance for regulatory supervision. Analysis of these indices should answer the question of whether energy entities apply the measures determined by the regulatory body with the goal of achieving increased economic performance through the application of incentive regulations. In Latvia, the tariff methodology determines the manner in which a proposed tariff should be submitted, i.e. determines the set of necessary data that must be submitted to the regulatory body. In the Ukraine, supervision of business plans is performed through accounting supervision and reports for the purposes of the regulatory body. Business or investment plans, among other things, must contain the amount of the annual budget, the source of financing and a detailed elaboration of costs. For the Ukrainian regulatory body, it is necessary to emphasize that various types of methods based upon benchmarking have been applied for many years, for which data on the costs for individual investments are more than welcome.

Responses to the questionnaire showed that in the majority of the countries, the regulatory body supervises the implementation of planned investment through the procedure of determining the tariffs for the new regulatory period. What is important in the determination of the prices for services and the inclusion of individual costs in the level of the revenues of the energy entity approved by the regulatory body is the implementation of investment from the investment cycle. Insofar as an individual investment is approved and included in investment plans, and the necessary assets are allocated for it in the regulatory period, this same investment cannot be included in the regulated expenditures in the new regulatory period. Therefore, it follows that supervision by the regulatory body is very important in the segment of supervising the implementation of the investment plans of a entities performing regulated activities.

If an energy entity does not implement a planned investment cycle, in some countries (Armenia, Latvia, Lithuania, Poland and the Ukraine) there is a reduction in the amounts of the regulated tariff items in the subsequent regulatory period. However, even more drastic solutions are possible, such as, for example, in Armenia where the regulatory body, in addition to reducing the amounts of the tariff items, can also issue a warning or revoke the license for performing energy operations. However, when this concerns a transmission system operator, the question is asked who will perform the activity if the license is revoked. Furthermore, monetary fines can be imposed as penalties for not fulfilling an investment cycle such as, for example, in the Ukraine of up to USD 16 000.

izrađuje temeljem Strategije energetskog razvitka i Programa provedbe Strategije.

Radi lakše provedbe postupka davanja suglasnosti na planove od strane regulatornog tijela i kasnijeg nadzora nad provedbom planova u pojedinim državama (Bugarska i Ukrajina) struktura sadržaja planova je predefinirana. U Litvi razvojni/investicijski planovi moraju zadovoljiti nužan minimum sadržaja planova, a to je:

- obrazac potpisan od strane odgovorne osobe sa svim potrebnim podacima djelatnika (imena, telefon, e-mail adresa) koji su sudjelovali u izradi planova,
- popis planiranih investicija koje moraju biti u skladu sa strategijom razvoja i dugoročnim planovima razvoja mreža, uključujući iznos potrebnih financijskih sredstava, izvore financiranja, terminski plan i slično,
- pisano obrazloženje u vidu investicijskog plana za razdoblje od tri godine iz kojeg je vidljiv učinak pojedine investicije, kako u tehničkom tako i ekonomskom, socijalnom i ekološkom pogledu. Isto tako potrebno je navesti utjecaj pojedine investicije na cijenu, kvalitetu usluge i sl. U odgovoru na pitanje iz Upitnika nije navedeno do koje naponske razine ili koje visine investicije je potrebno pisati ovako detaljna pojašnjenja razloga za pojedinu investiciju,
- energetski subjekt treba osigurati i druge podatke ili dokumente ukoliko regulatorno tijelo ustanovi da su potrebni za mjerodavan stav regulatornog tijela.

U dijelu Upitnika koji se odnosi na povezanost planova i regulatornih parametara, kao što je to stopa povrata na kapital, većina regulatornih tijela odgovorila je da institucija koja odobrava planove ne treba predefinirati pojedine regulatorne parametre kojima bi se služili u analizi planova. Izuzetak je Bugarska u kojoj regulatorno tijelo može dati instrukcije, u smislu davanja informacije o aproksimativnom iznosu pojedinih regulatornih parametara, kao što je npr. stopa povrata na kapital kojom se energetski subjekt može koristiti prilikom izrade planova razvoja/investicija.

Under Croatian law [8], a monetary fine for an energy entity in the amount of up to 50 000 kunas is stipulated if development and construction plans are not prepared, i.e. if they are not prepared according to the Energy Development Strategy and the Program for the Implementation of the Strategy.

To facilitate implementation, the procedures for issuing approval for plans by the regulatory body and subsequent supervision of the implementation of plans in some countries (Bulgaria and the Ukraine), the structure of the content of the plans are predefined. In Lithuania, development/investment plans must include the necessary minimum contents of the plans, as follows:

- a form should be signed by the responsible persons, with all the necessary data on the employees (names, telephone numbers and e-mail addresses) who participated in the preparation of the plans,
- there should be a list of the planned investments, which must be pursuant to the development strategy and long-range plans for the development of the network, including the amount of the necessary financial assets, the sources of financing, schedule etc.,
- there should be a written explanation regarding the investment plan for the period of three years, from which the impact of individual investments is visible, in the economic, social and ecological aspects. Furthermore, it is necessary to state the impact of individual investments on price, quality of service etc. The responses to a question from the questionnaire do not indicate the voltage level or the level of investment that require a detailed written explanation of the reasons for an individual investment,
- the energy entity should also provide other data or documents if the regulatory body deems that they are necessary in order for it to determine its position.

In the part of the questionnaire that refers to the connection between plans and regulatory parameters, such as the rate of return on capital, the majority of the regulatory bodies answered that the institution that approves plans does not have to predefine the individual regulatory parameters that it would use in the analysis of the plans, with the exception of Bulgaria in which the regulatory body can provide instructions in the sense of furnishing information on the approximate amounts of regulatory parameters, such as, for example, the rate of return on capital that an energy entity can use in preparing development/investment plans.

Zaključak koji se može izvući iz odgovora na pitanja iz Upitnika je da regulatorna tijela ukoliko imaju u nadležnosti davanje suglasnosti na planove razvoja/investicija OPS-a i ODS-a, u načelu suglasnost daju na mogućnost realizacije predviđenih investicija u financijskom pogledu te na rezultate koji se postižu predviđenim investicijama. Pod rezultatima smatra se povećanje učinkovitosti subjekata koji obavljaju regulirane djelatnosti ili povećanje razine kvalitete opskrbe. Ono što je potrebno naglasiti kao zaključak razmatranja odgovora na Upitnik je da se analizirana regulatorna tijela ne miješaju u koncepcijska tehnička rješenja u planovima razvoja i izgradnje mreža.

Da bi se moglo govoriti o povećanju učinkovitosti koja je rezultat primjene poticajne regulacije i o utjecaju razine odobrenih investicija na razinu dozvoljenog prihoda reguliranog subjekta, potrebno je dati prikaz, odnosno analizu, mogućih regulatornih politika u primjeni poticajne regulacije. Pri tome važnu ulogu ima osnovica na koju se primjenjuje faktor učinkovitosti te dinamika realizacije predviđenih investicija i amortizacijska politika.

## 3 UTJECAJ REGULATORNE POLITIKE NA DOZVOLJENI PRIHOD

Do sada je bilo riječi o nadležnosti regulatornog tijela u donošenju planova razvoja/investicija, a da se pri tome nije analizirala regulatorna politika u kojoj važnu ulogu ima cilj koji se želi postići pojedinim investicijskim ciklusom te razina odobrenih investicija koje se uključuju u regulirane troškove. Kontekst regulatorne politike koji se razmatra u ovom članku prvenstveno se odnosi na poticajnu regulaciju čije su značajke u detalje razmatrane u literaturi pod [6], a za koju je, ukoliko se radi o metodi regulacije maksimalnog prihoda, karakteristična sljedeća formula:

The conclusion that can be drawn from the responses to the questions on the questionnaire is that the regulatory bodies, insofar as they have the authority to approve the development/investment plans of the transmission system operator and the distribution system operator, in principle issue approval based upon the feasibility of the implementation of the planned investments in the financial aspect and based upon the results to be achieved by the planned investments. Results include the increased efficiency of the entities performing regulated activities or improved quality of the supply. It is necessary to emphasize that a conclusion drawn from a review of the responses to the questionnaire is that the analyzed regulatory bodies do not interfere in the conceptual technical solutions of the network development and investment plans.

In order to speak about the increased efficiency resulting from the application of incentive regulations and the impact of the level of approved investments on the level of the allowed revenue of entities performing regulated activities, it is necessary to provide a presentation, i.e. an analysis, of the potential regulatory policies in the application of incentive regulations. Important roles are played by the base upon which the efficiency factor is applied, the dynamics of the implementation of planned investments and the depreciation policy.

## 3 THE IMPACT OF REGULATORY POLICIES ON ALLOWED REVENUE

Thus far, the authority of the regulatory body in the adoption of development/investment plans has been discussed without analyzing the regulatory policies, in which the desired goal to be achieved by an individual investment cycle and the level of approved investments included under regulated expenditures have important roles. The context of the regulatory policies that are discussed in this article primarily refers to incentive regulation, the characteristics of which are discussed in detail in the literature [6], and for which, insofar as they concern methods for the regulation of maximum revenue, are characterized by the following formula:

$$P_{\max t} = (1 + CPI_t - X_t) \cdot P_{\max(t-1)} - KP_t$$

$$R_{\max t} = (1 + CPI_t - X_t) \cdot R_{\max(t-1)} - KP_t \qquad (1)$$

gdje je:

$P_{\max t}$ – gornja granica dozvoljenog prihoda u godini $t$,

where:

$R_{\max t}$ – the upper limit of revenue, i.e. revenue-cap, in year $t$,

$P_{max\,(t-1)}$ – gornja granica dozvoljenog prihoda u godini $t$ -1,
$CPI_t$ – indeks potrošačkih cijena u godini $t$,
$X_t$ – faktor učinkovitosti u godini $t$,
$KP_t$ – faktor korekcije u godini $t$.

Mehanizam poticajne regulacije prije svega nastoji kroz poticaje ($X$-faktor) povećati učinkovitost energetskih subjekta. Pri tome vrijedi pretpostavka da je energetski subjekt u stanju kontrolirati razinu svojih troškova. Za troškove za koje se smatra da ih energetski subjekt ne može kontrolirati, odnosno da su izvan kontrole subjekta, kao što su to npr. porezi, naknada za regulaciju, troškovi koje je prouzročila viša sila i sl., ne može se očekivati povećanje učinkovitosti subjekta na račun njihovog smanjenja. Stoga se poticaji primjenjuju na razinu kontroliranih troškova, dok se nekontrolirani troškovi smatraju prolaznim i u cjelokupnom iznosu se prebacuju na kupca. Detaljna elaboracija granice između kontroliranih i nekontroliranih troškova zahtijeva dublje analize od strane regulatornog tijela. Kao primjer troškova koji se mogu svesti u sferu kontroliranih i nekontroliranih troškova su troškovi tehničkih gubitaka u mreži. Ukoliko regulatorno tijelo smatra da su gubici u potpunosti nekontrolirani trošak, prihvaća njihovu razinu, odnosno njihov trošak, u iznosu koji prijavljuje energetski subjekt. U tom slučaju energetski subjekt neće imati nikakav poticaj da ih smanji, bilo u vidu troška bilo u vidu fizičkih gubitaka izraženih u kWh. Međutim, ukoliko ih regulatorno tijelo smatra kontroliranim troškom, nastojat će ih kroz regulatornu politiku svesti u granice koje se sa stajališta regulatornog tijela čine opravdanima.

Kada se radi o kontroliranim troškovima, regulatorna politika razlikuje dvije grupe troškova:

- operativne troškove (engl. *Operating Expanditures – OPEX*), troškovi koje je moguće kontrolirati u kratkoročnom razdoblju i
- kapitalne troškove (engl. *Capital Expanditures – CAPEX*), troškove koje je moguće kontrolirati u dugoročnom razdoblju.

U *OPEX* se ubrajaju troškovi osoblja, materijalni troškovi, troškovi održavanja, ostali troškovi poslovanja i sl. Troškovi koje je moguće prilagođavati u relativno kratkom roku. S druge pak strane, *CAPEX* se u kratkoročnom razdoblju može promatrati kao fiksni trošak budući da se i prvenstveno radi o troškovima koji se vežu uz investicije u razvoj mreža i poboljšanje kvalitete opskrbe. *CAPEX* je moguće podijeliti u dvije grupe – amortizaciju i povrat sredstava koji se definira kao godišnja stopa povrata primijenjena na neamortizirani dio ulaganja. Povrat sredstava u načelu utvrđuje regulator-

$R_{max\,(t-1)}$ – the upper limit of revenue, i.e. revenue-cap, in year $t$ -1,
$CPI_t$ – the consumer price index in year $t$,
$X_t$ – the efficiency factor in year $t$,
$KP_t$ – the correction factor in year $t$.

The mechanism of incentive regulation primarily attempts to increase the efficiency of energy entities through incentives (the $X$-factor). It is presumed that an energy entity is in a position to control the level of its expenditures. For expenditures presumed to be non-controllable by an energy entity, i.e. that are out of the control of the entity, such as, for example, taxes, regulation charges, expenditures due to force majeure etc., it is not possible to expect that the entity will achieve increased efficiency by reducing them. Therefore, incentives are applied at the level of controllable costs, while non-controllable costs are considered to be transitory and are transferred in their entirety to the customers. A detailed elaboration of the boundary between controllable and non-controllable expenditures requires in-depth analysis by the regulatory body. An example of expenditures that can be classified within the spheres of both controllable and non-controllable expenditures are the costs of technical losses in the network. Insofar as the regulatory body considers the losses to be entirely non-controllable expenditures, it accepts their level, i.e. their cost, in the amount that the energy entity reports. In this case, the energy entity will not have any incentive to reduce them, whether in the aspect of expenditures or the aspect of physical losses expressed in kWh. However, insofar as the regulatory body considers them to be controllable expenditures, it will attempt to lower them through regulatory policy to within the limits considered justified from the standpoint of the regulatory body.

Concerning controllable expenditures, regulatory policy differentiates between two groups of expenditures:

- Operating expenditure – *OPEX*, expenditure that can be controlled within a short-term period
- Capital expenditure – *CAPEX*, expenditure that can be controlled within a long-term period.

Under *OPEX* are included personnel costs, material costs, maintenance costs, other operating costs etc. These are expenditures that can be adjusted within a relatively short period. On the other hand, *CAPEX* can be considered as fixed expenditures within a short-term period, primarily concerning expenditures in connection with investment in network development and improvement in the quality of the supply. *CAPEX* can be divided into two groups – depreciation and return on assets, defined as the annual rate of return applied to the non-depreciated portion of investment. In principle, the return

no tijelo na osnovi troška kapitala subjekata koji obavljaju regulirane djelatnosti [7].

Imajući u vidu da regulatorno tijelo u načelu može regulirati dvije kategorije troškova, moguće je definirati dva pristupa u regulaciji. Prvo, regulatorno tijelo može primjenjujući pojedinu metodu poticajne regulacije zasebno razmatrati *OPEX* i *CAPEX*. Ovakav pristup poznat je pod nazivom regulatorni pristup slaganja blokova, budući da se sastoji od dvije komponente, odnosno bloka, za koje regulatorno tijelo pojedinačno utvrđuje opravdanu razinu.

Drugi pristup se odnosi na regulatornu politiku u kojoj regulatorno tijelo *OPEX* i *CAPEX* razmatra kao integrirani trošak na koji se sumarno primjenjuje odabrana metoda poticajne regulacije. Ovakav pristup poznat je pod nazivom regulatorni pristup ukupnog troška. *TOTEX* označava sumu *OPEX*-a i *CAPEX*-a. U nastavku razmatra se svaki od pristupa pojedinačno.

### 3.1 Regulatorni pristup slaganja blokova

U regulatornom pristupu slaganja blokova regulatorno tijelo mora odvojeno analizirati učinkovitu, odnosno opravdanu razinu, *OPEX*-a i *CAPEX* -a. Pri ocjenjivanju razine učinkovitosti i opravdanosti *OPEX*-a čest je slučaj da regulatorna tijela koriste razne metode ravnanja prema mjerilu [7]. Međutim, utvrđivanje faktora učinkovitosti $X$ u formuli za poticajnu regulaciju (1) zahtijeva puno složeniji postupak, uključujući i diskrecijske odluke regulatornih tijela, od direktnog uvrštavanja rezultata dobivenih primjenom neke od poznatih metoda ravnanja prema mjerilu.

Dozvoljena razina *CAPEX*-a utvrđuje se na osnovi investicijskih planova energetskih subjekata predviđenih za sljedeće regulatorno razdoblje. Na osnovi predloženih investicija, regulatorno tijelo procjenjuje koje investicije uključiti u regulatornu osnovicu sredstava. Investicije koje su uključene u regulatornu osnovicu sredstava bit će u potpunosti uključene u trošak amortizacije te će se na neamortizirani dio primijeniti stopa povrata na uloženi kapital.

Čest je slučaj da se predviđena razina investicija promatra kao trošak koji se prihvaća na razini prijedloga energetskih subjekata. Ukoliko regulatorno tijelo u potpunosti prizna predložene investicije, kod energetskog subjekta se stvara poticaj da prikazuje što veću razinu budućih investicija ne vodeći se opravdanim razlozima kao što su smanjenje gubitaka u mreži ili postizanje optimalne, odnosno propisane razine kvalitete opskrbe. Pri tome energetski subjekt ima u vidu da će se veća

on assets is determined by the regulatory body on the basis of the capital expenditures of the entities performing regulated activities [7].

Bearing in mind that the regulatory body can in principle regulate the two categories of expenditures, it is possible to define two approaches to regulation. First, when the regulatory body applies an individual incentive regulation method, it can consider *OPEX* and *CAPEX* separately. Such an approach is known as the building block approach, since it consists of two components, i.e. blocks, for which the regulatory body determines the justifiable levels individually.

The second approach refers to the regulatory policy in which the regulatory body considers *OPEX* and *CAPEX* as an integrated expenditure, to which the selected incentive regulation method is summarily applied. Such an approach is known as the total expenditure, *TOTEX*, regulatory approach. *TOTEX* represents the sum of *OPEX* and *CAPEX*. Each approach will be discussed separately.

### 3.1 The building block regulatory approach

In the building block regulatory approach, the regulatory body must analyze the efficiency or justified level of *OPEX* and *CAPEX* separately. In assessing the efficiency and justified level of *OPEX*, a regulatory body frequently employs various benchmarking methods [7]. However, the determination of the efficiency factor $X$ in the formula for incentive regulation (1) requires a far more complex procedure, including discretional decisions by the regulatory bodies, such as the direct classification of the results obtained from the application of some of the well-known benchmarking methods.

The allowed level of *CAPEX* is determined on the basis of the investment plans of energy entities for the subsequent regulatory period. On the basis of the proposed investments, the regulatory body assesses which investments to include in the regulatory asset base (*RAB*). Investments that are included in the regulatory asset base will be fully included in the depreciation cost, and the return rate on invested capital will be applied to the non-depreciated part.

It is frequently the case that the investment level is considered as an expenditure which is accepted at the level of the proposals by the energy entities. Insofar as the regulatory body recognizes the proposed investments in full, incentive is created for the energy entity to show the highest possible level of future investments, whether or not they are based upon justified reasons such as reducing losses in the network or achieving the optimal, i.e.

razina investicija uključiti u regulatornu osnovicu sredstava, a time će biti i veći povrat sredstava, što će se u konačnici odraziti i na profite. Energetskom subjektu bit će u interesu prikazati što veće investicije u budućem regulatornom razdoblju. Povodeći se tim načelom postoji i mogućnost da pojedine *OPEX* troškove energetski subjekt prikaže kao *CAPEX*. Na taj način pojedini *OPEX* troškovi nisu uključeni u poticajni mehanizam povećanja učinkovitosti na razini *OPEX* troškova. Time će se postići privid manjih *OPEX* troškova, odnosno postizanje veće učinkovitosti energetskog subjekta u sferi *OPEX* troškova. Strateška alokacija *OPEX*-a pod *CAPEX*, odnosno povećanje regulatorne osnovice sredstava na taj način, uočena je već u nekim slučajevima regulatornog nadzora posebice u Velikoj Britaniji [10].

Postavlja se pitanje na koji način regulatorno tijelo može reagirati ukoliko se tijekom regulatornog razdoblja ne realiziraju sve predviđene investicije odobrene od strane regulatornog tijela. Ukoliko se pokaže da nisu realizirane sve predviđene investicije, regulatorno tijelo može u sljedećem regulatornom razdoblju utvrditi niže cijene usluga, odnosno može ne dozvoliti ponovno uključivanje nerealiziranih investicija u regulatornu osnovicu sredstava. Međutim, da bi regulatorni pristup bio dosljedan i razvidan za obje strane, regulatorno tijelo i energetski subjekt, regulatorno tijelo može utvrditi donju i gornju granicu za realizaciju investicija iz plana poslovanja i razvoja. Prekomjerne investicije neće biti uopće uključene u regulatornu osnovicu sredstava ili će biti uključene samo djelomično. Ono što predstavlja problem u takvom regulatornom pristupu je da energetski subjekt nema poticaja za povećanje učinkovitosti u segmentu *CAPEX* -a. Naime, ukoliko se ostvari manji *CAPEX* od predviđenog, regulatorno tijelo će u načelu u budućem regulatornom razdoblju kao osnovicu za izračun imati manji *CAPEX*, bez obzira da li se radi o uštedama na račun podinvestiranosti (manjeg razmjera investicija od odobrenih) ili o povećanju produktivnosti energetskog subjekta. Energetski subjekt ne ostvaruje nikakve financijske koristi od povećanja učinkovitosti u segmentu *CAPEX* -a.

the stipulated, level of supply quality. The energy entity must bear in mind that a higher level of investment will be included in the regulatory asset base and, therefore, there will be a greater return on assets, which will ultimately reflect upon profits. Consequently, it is in the interest of the energy entity to show the maximum investments in the future regulatory period. Consequently, there is also the possibility that an individual *OPEX* by an energy entity is shown as a *CAPEX*. In this manner, individual operating expenditures are not included in the incentive mechanism for increasing efficiency at the level of *OPEX*. In this manner, apparently lower operating expenditures will be achieved, i.e. greater efficiency of the energy entity in the sphere of *OPEX*. The strategic allocation of operating expenditures under capital expenditures, i.e. increasing the regulatory asset base in this manner, has already been noted in some cases of regulatory supervision, especially in Great Britain [10].

The question is posed regarding how a regulatory body can react if all the planned investments that it has approved have not been made during a regulatory period. Insofar as all the planned investments have not been implemented, during the subsequent regulatory period the regulatory body can set lower prices for services or can prohibit non-implemented investments from being included in the regulatory asset base again. However, in order for the regulatory procedure to be consistent and transparent for both sides, the regulatory body and the energy entity, the regulatory body can set lower and upper limits for the implementation of investment from the business and development plans. Excessive investment will not be included in the regulatory asset base or will be included only in part. What represents a problem in such a regulatory approach is that an energy entity does not have any incentive to increase efficiency in the *CAPEX* segment. If there is lower *CAPEX* than anticipated, in principle the regulatory body will have lower *CAPEX* as a base for calculation in the subsequent regulatory period, regardless of whether this concerns savings at the expense of under investment (lower investment than approved) or increased productivity by the energy entity. Therefore, the energy entity does not derive any financial benefits from increasing efficiency in the *CAPEX* segment.

Tablica 1 – Pojednostavljen primjer izračuna dozvoljenog prihoda primjenom regulatornog pristupa slaganja blokova
Table 1 – Simplified example of the calculation of the allowed revenue through the application of the building block regulatory approach

| | |
|---|---|
| **Regulatorni parametri / Regulatory parameters** | |
| *OPEX* – faktor učinkovitosti / *OPEX* – efficiency factor | 90 % |
| Godišnje smanjenje *OPEX*-a / Annual reduction in *OPEX* | 2,60 % |
| Razdoblje amortizacije (godina) / Depreciation period (years) | 20 |
| Stopa povrata / Rate of return | 7 % |

| | Godine / Year | | | | |
|---|---|---|---|---|---|
| | 0. | 1. | 2. | 3. | 4. |
| | ($10^6$ HRK) | ($10^6$ HRK) | ($10^6$ HRK) | ($10^6$ HRK) | ($10^6$ HRK) |
| **Odobrene investicije / Authorized investments** | | 1 000,00 | 1 200,00 | 1 000,00 | 1 400,00 |
| | | | | | |
| Odobrena amortizacija / Authorized depreciation | | | | | |
| – od prethodnih investicija / from previous investments | | 700,00 | 700,00 | 700,00 | 700,00 |
| – od investicija iz 1. godine / from investments from the 1st year | | 50,00 | 50,00 | 50,00 | 50,00 |
| – od investicija iz 2. godine / from investments from the 2nd year | | | 60,00 | 60,00 | 60,00 |
| – od investicija iz 3. godine / from investments from the 3rd year | | | | 50,00 | 50,00 |
| – od investicija iz 4. godine / from investments from the 4th year | | | | | 70,00 |
| **– Ukupno odobrena amortizacija / Total authorized depreciation** | | 750,00 | 810,00 | 860,00 | 930,00 |
| **Izračun regulatorne osnovice (*ROS*) / Calculation of the regulatory asset base (*RBA*)** | | | | | |
| – početni *ROS* / initial *RBA* | | 3 000,00 | 3 250,00 | 3 640,00 | 3 780,00 |
| – plus: nove investicije / plus: new investments | | 1 000,00 | 1 200,00 | 1 000,00 | 1 400,00 |
| – minus: amortizacija / minus: depreciation | | 750,00 | 810,00 | 860,00 | 930,00 |
| – konačni *ROS* / final *RBA* | 3 000,00 | 3 250,00 | 3 640,00 | 3 780,00 | 4 250,00 |
| **– prosječni *ROS* / mean *RBA*** | | 3 125,00 | 3 445,00 | 3 710,00 | 4 015,00 |
| **Izračun ukupnog dopuštenog prihoda / Calculation of total authorized revenue** | | | | | |
| – *OPEX* / *OPEX* | 2 400,00 | 2 337,60 | 2 276,82 | 2 217,63 | 2 159,97 |
| – amortizacija / depreciation | 700,00 | 750,00 | 810,00 | 860,00 | 930,00 |
| – povrat sredstava (stopa povrata **ROS*) / return on assets (return rate **RBA*) | 210,00 | 218,75 | 241,15 | 259,70 | 281,05 |
| **– dozvoljeni prihod / allowed revenue** | 3 310,00 | 3 306,35 | 3 327,97 | 3 337,33 | 3 371,02 |

Nadalje, problem koji se javlja prilikom uspostave ciljane razine investicija je da ta razina mora odražavati učinkovitu razinu svake pojedine investicije koja se uključuje u regulatornu osnovicu sredstava. Da bi ovakav pristup bio moguć, regulatorno tijelo mora imati dovoljnu količinu informacija kao i dovoljan broj stručno osposobljenih ljudi, što se u praksi često pokazalo neostvarivim. Problem se dodatno komplicira budući da je primjena neke od metoda ravnanja prema mjerilu na *CAPEX* -a poprilično složen i težak postupak za primjenu, stoga ga regulatorna tijela izbjegavaju. Polazište za definiranje investicijskog plana

Furthermore, a problem that arises when establishing a target level of investment is that it must reflect the level of the performance of each individual investment that is included in the regulatory asset base. In order for this approach to work, the regulatory body must have a sufficient amount of information as well as a sufficient number of qualified personnel, which in practice is often unfeasible. The problem is additionally complicated because the application of some benchmarks to *CAPEX* is a fairly complex and difficult procedure and, therefore, regulatory bodies avoid it. The starting point for the definition of an investment plan is growth in consumption and the

je porast potrošnje te zamjena postojeće opreme. Ti čimbenici se razlikuju kada je riječ o različitim energetskim subjektima te mogu značajno utjecati na rezultate primjene metode ravnanja prema mjerilu. Nadalje, iako se radi o istovrsnim investicijama i istoj razini investicija, na rezultate metoda ravnanja prema mjerilu može utjecati i različito vrijeme započinjanja investicije i dinamika realizacije investicije, kao i utvrđena razina kvalitete opskrbe. Kvaliteta opskrbe kao funkcija regulacije do sada se često promatrala kao zasebna funkcija od funkcije regulacije cijena usluga, iako iskustva pokazuju da regulatorna tijela sve više nastoje razviti integrirane modele regulacije kojima bi se izbjegli svi dosadašnji rizici primjene pojedine metode regulacije [9]. Tablica 1 prikazuje pojednostavljeni primjer izračuna dozvoljenog, odnosno od strane regulatornog tijela odobrenog prihoda regulatornim pristupom slaganja blokova. Vrijednosti za dozvoljene investicije (na godišnjoj razini od 1 000 milijuna kuna), početni *OPEX* (2 400 milijuna kuna) i amortizaciju od prethodnih investicija (700 milijuna kuna) koje su pri tome korištene na razini su vrijednosti HEP ODS-a [12]. Od vrijednosti prikazanih u literaturi pod [12] oduzeti su troškovi koji po procjeni autora otpadaju na priključke. Od regulatornih parametara utvrđeni su:

- regulatorno razdoblje od 4 godine,
- faktor učinkovitosti za *OPEX* u vrijednosti 90 %, što godišnje iznosi smanjenje *OPEX*-a 2,6 %,
- linearna amortizacija na razdoblje od 20 godina,
- stopa povrata od 7 %.

Iz tablice 1 vidljivo je da, ukoliko se svi parametri definiraju kako je prethodno rečeno, dozvoljeni prihod subjekata koji obavljaju regulirane djelatnosti kroz 4 godine regulatornog razdoblja ostaje na skoro istoj razini. Regulatorna politika, odnosno ocjena potrebne razine povećanja učinkovitosti, može imati značajan utjecaj na regulirani prihod energetskog subjekta.

### 3.2 Regulatorni pristup ukupnih troškova

U regulatornom pristupu ukupnih troškova regulatorno tijelo kada utvrđuje razinu opravdane učinkovitosti ne razlikuje između *OPEX*-a i *CAPEX* -a, stoga faktor učinkovitosti $X$ primjenjuje na sumu *OPEX*-a i *CAPEX*-a, odnosno na ukupan trošak (*TOTEX*) (tablica 2). U ovom slučaju regulatorno tijelo ne mora utvrđivati odvojeno opravdanu razinu investicija za sljedeće regulatorno razdoblje, već analizu provodi za ukupne troškove. U ovom pristupu regulatorno tijelo utvrđuje $X$-faktor na osnovi razine učinkovitosti iz prethodnih regulator-

replacement of existing equipment. These factors differ among various energy entities and can significantly influence the results of the benchmarking method applied. Moreover, although this concerns the same types of investments and the same level of investment, the results of the benchmarking method can be affected by differing times for the beginning of investments and the dynamics of the implementation of the investments, as well as the determined level of the quality of the supply. Up to now, the quality of the supply as a function of regulation has been frequently viewed as a function that is separate from the function of the regulation of the prices for services, although experience shows that the regulatory bodies are increasingly attempting to develop integrated models of regulation that avoid all the risks inherent in the individual regulatory methods that have been applied [9]. Table 1 shows a simplified example of the calculation of allowed revenue, i.e. revenue authorized by the regulatory body, using the building block approach. The values for allowed investments (at an annual level of 1 000 million kunas), the initial *OPEX* (2 400 million kunas) and depreciation from previous investments (700 million kunas) were previously used at the level of the HEP Distribution System Operator (HEP ODS d,o.o.) [12]. From the values presented in the literature under [12], expenditures have been deducted that the authors consider to be connection costs. The following regulatory parameters have been established:

- a regulatory period of 4 years,
- a efficiency factor for *OPEX* with a value of 90 %, which amounts to an annual reduction in *OPEX* of 2,6 %,
- linear depreciation during a period of 20 years,
- a rate of return of 7 %.

From Table 1, it is evident that, when all the parameters are defined as above, the allowed revenue of a entities performing regulated activities during a 4-year regulatory period remains at nearly the same level. Thus, regulatory policy, i.e. the assessment of the necessary level of increasing efficiency, can have a significant impact on the regulated revenue of an energy entity.

### 3.2 The regulatory approach of total expenditure

In the regulatory approach of total expenditure, when the regulatory body determines the level of justified efficiency it does not differentiate between *OPEX* and *CAPEX*, and therefore the efficiency factor $X$ is applied to the sum of *OPEX* and *CAPEX*, i.e. to the total expenditure (*TOTEX*) (Table 2). Therefore, in this case the regulatory body does not need to determine the justified levels of investment separately for the subsequent regulatory period but

nih razdoblja. Ukoliko je energetski subjekt uspio u prethodnim razdobljima podići razinu učinkovitosti, koju će zadržati i u budućem razdoblju, *X*-faktor će biti niži. Naime, ovo je značajna razlika u regulatornom pristupu u odnosu na pristup slaganja blokova u kojem se prije svega ocjenjuje opravdanost razine predviđenih investicija u budućem razdoblju, ali ne i učinkovita razina *CAPEX* -a.

analyzes the total expenditure instead. In this approach, the regulatory body determines the *X*-factor on the basis of the level of efficiency from the previous regulatory periods. If the energy entity has successfully achieved the specified level of efficiency during the previous periods, which will also be maintained during the future period, the *X*-factor will be lower. This is a significant difference in the regulatory approach in comparison to the building block approach, in which the justification of the level of the anticipated investments in the future period is assessed but not the efficiency level at the *CAPEX* level.

Tablica 2 – Pojednostavljen primjer izračuna dozvoljenog prihoda primjenom regulatornog pristupa ukupnog troška
Table 2 – A simplified example of the calculation of the allowed revenue through the application of the total expenditure regulatory approach

| **Regulatorni parametri / Regulatory parameters** | |
|---|---|
| Ukupni faktor učinkovitosti / Total efficiency factor | 88 % |
| Godišnja stopa porasta učinkovitosti / Annual rate of efficiency growth | 4 % |

| | **Godina / Year** | | | |
|---|---|---|---|---|
| | 0. | 1. | 2. | 3. |
| | ($10^6$ HRK) | ($10^6$ HRK) | ($10^6$ HRK) | ($10^6$ HRK) |
| *OPEX* / *OPEX* | 2 400,00 | 2 304,00 | 2 212,00 | 2 123,00 |
| Amortizacija / Depreciation | 700,00 | 672,00 | 645,00 | 619,00 |
| Povrat sredstava / Return on assets | 300,00 | 288,00 | 276,00 | 265,00 |
| **Dozvoljeni prihod / Allowed revenue** | 3 400,00 | 3 264,00 | 3 133,00 | 3 008,00 |

U ovom pristupu problem ocjenjivanja opravdanosti razine investicija je na svojevrstan način izbjegnut. Nadalje, budući da ovaj pristup ne razlikuje *OPEX* i *CAPEX*, moguće je da energetski subjekt postigne odgovarajuću razinu učinkovitosti balansirajući između *OPEX*-a i *CAPEX* -a, odnosno između, u klasičnom smislu teorije produktivnosti, rada i kapitala. Kod regulatornog pristupa ukupnih troškova, regulatorno tijelo ne mora razvijati kriterije za ocjenjivanje prijedloga investicija, već analizira *TOTEX*, koji uključuje i investicije, te utvrđuje *X*-faktor na osnovi analize *TOTEX*-a.

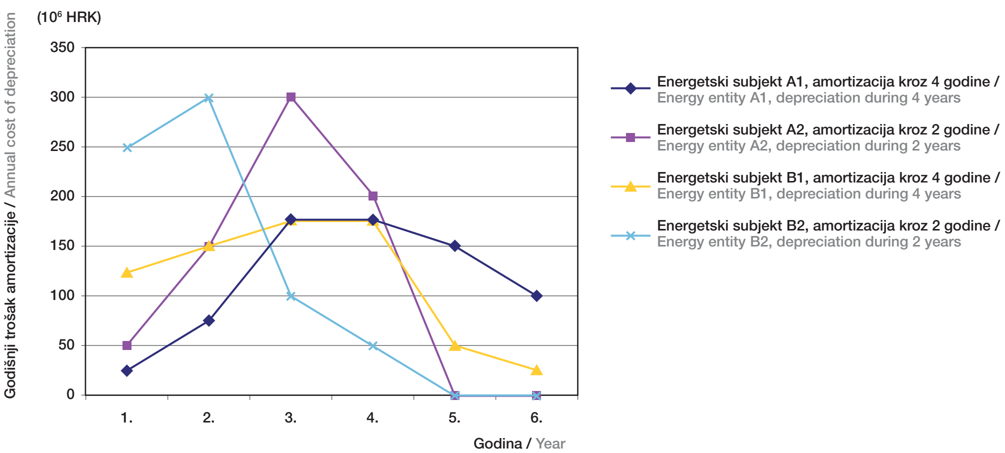
In this approach, the problem of assessing the justification of the level of investment is avoided in its own way. Furthermore, since this approach does not differentiate between *OPEX* and *CAPEX*, it is possible for an energy entity to achieve the suitable level of efficiency by balancing *OPEX* and *CAPEX* or labor and capital, in the classical sense of the theory of productivity. Therefore, in the regulatory approach of total expenditure, the regulatory body does not have to develop criteria for the assessment of an investment proposal but instead analyzes *TOTEX*, which also includes investment, and determines the *X*-factor on the basis of analysis of the *TOTEX*.

Tablica 3 – Pojednostavljen primjer utjecaja različite dinamike investiranja i amortizacijske politike na godišnji trošak amortizacije
Table 3 – A simplified example of the influence of various dynamics of investment and depreciation policies on the annual depreciation cost

| | | | | | |
|---|---|---|---|---|---|
| **Energetski subjekt A1, amortizacija kroz 4 godine /** Energy Entity A1, depreciation during 4 years | | | | | |
| **Godina /** Year | **Investicije /** Investments **($10^6$ HRK)** | **Godišnji trošak amortizacije po investicijama /** Annual depreciation cost according to investments **($10^6$ HRK)** | | | **Troškovi amortizacije /** Depreciation costs **($10^6$ HRK)** |
| | | 1. | 2. | 3. | |
| 1. | 100 | 25 | | | 25 |
| 2. | 200 | 25 | 50 | | 75 |
| 3. | 400 | 25 | 50 | 100 | 175 |
| 4. | | 25 | 50 | 100 | 175 |
| 5. | | | 50 | 100 | 150 |
| 6. | | | | 100 | 100 |
| **Ukupno /** Total | 700 | 100 | 200 | 400 | 700 |
| | | | | | |
| **Energetski subjekt A2, amortizacija kroz 2 godine /** Energy Entity A2, depreciation during 2 years | | | | | |
| 1. | 100 | 50 | | | 50 |
| 2. | 200 | 50 | 100 | | 150 |
| 3. | 400 | | 100 | 200 | 300 |
| 4. | | | | 200 | 200 |
| 5. | | | | | 0 |
| 6. | | | | | 0 |
| **Ukupno /** Total | 700 | 100 | 200 | 400 | 700 |
| | | | | | |
| **Energetski subjekt B1, amortizacija kroz 4 godine /** Energy Entity B1, depreciation during 4 years | | | | | |
| 1. | 500 | 125 | | | 125 |
| 2. | 100 | 125 | 25 | | 150 |
| 3. | 100 | 125 | 25 | 25 | 175 |
| 4. | | 125 | 25 | 25 | 175 |
| 5. | | | 25 | 25 | 50 |
| 6. | | | | 25 | 25 |
| **Ukupno /** Total | 700 | 100 | 200 | 400 | 700 |
| | | | | | |
| **Energetski subjekt B2, amortizacija kroz 2 godine /** Energy Entity B2, depreciation during 2 years | | | | | |
| 1. | 500 | 250 | | | 250 |
| 2. | 100 | 250 | 50 | | 300 |
| 3. | 100 | | 50 | 50 | 100 |
| 4. | | | | 50 | 50 |
| 5. | | | | | 0 |
| 6. | | | | | 0 |
| **Ukupno /** Total | 700 | 500 | 100 | 100 | 700 |

Problem koji se javlja u regulatornom pristupu ukupnih troškova je vezan uz ročnost investicija. Naime, *CAPEX* se, uključujući amortizaciju i povrat sredstava, proteže kroz niz godina. Stoga bi prilikom primjene metoda ravnanja prema mjerilu analiza trebala u obzir uzeti razdoblje od nekoliko godina, a ne da se provodi na troškovima predviđenim samo za jednu godinu. Kao ilustrativni primjer dan je prikaz u kojem na *CAPEX* značajno utječe dinamika realizacije investicije, pri tome je prikazan samo trošak amortizacije, ali ne i povrat sredstava (tablica 3). Ukoliko bi se u analizi promatrala samo jedna godina, npr. druga godina realizacije investicije, energetski subjekt A1 bio bi učinkovitiji od energetskog subjekta B1, budući da su troškovi (75 milijuna kuna) energetskog subjekta A1 znatno niži od troškova (150 milijuna kuna) energetskog subjekta B1. Obrnuti slučaj bi se dogodio ukoliko bi se analiza provela u kasnijim godinama. Taj pojednostavljeni primjer naglašava važnost uključivanja dužeg razdoblja u analizu *TOTEX*-a metodom ravnanja prema mjerilu, što s praktične strane komplicira analizu budući da se mora analizirati veći skup podataka. Analiza se dodatno komplicira ukoliko se u obzir uzme različita računovodstvena praksa, što prikazuje tablica 3. Naime, energetski subjekti A1 i A2, odnosno B1 i B2, imaju istu dinamiku investiranja, međutim koriste različita amortizacijska razdoblja, stoga se njihov trošak amortizacije u pojedinoj godini značajno razlikuje (slika 3).

A problem that arises in the total expenditure regulatory approach is connected with investment maturity. *CAPEX*, including depreciation and return on assets, occurs over a series of years. Therefore, when applying the benchmarking method, analysis should take a period of several years into account and should not be performed for expenditures anticipated for only one year. An illustrative example is presented in which *CAPEX* significantly influences the dynamics of the investment, in which only the deprecation cost is shown and not the return on assets (Table 3). If only one year were considered in the analysis, for example the second year of the investment, Energy Entity A1 would be more efficient than Energy Entity B1, since the expenditures (75 million kunas) of Energy Entity A1 are significantly lower than the expenditures (150 million kunas) of Energy Entity B1. The reverse situation would occur if the analysis were performed in later years. This simplified example emphasizes the importance of including a longer period of analysis in the *TOTEX* benchmarking method, which from the practical aspect complicates analysis since it necessitates the analysis of a larger group of data. Analysis is further complicated insofar as various accounting practices are taken into account, as shown in Table 3. Energy Entities A1 and A2, i.e. B1 and B2, have the same dynamics of investment. However, they use different depreciation periods and, therefore, their depreciation costs in an individual year differ significantly (Figure 3).




**Slika 3**
Prikaz godišnjeg troška amortizacije za energetske subjekte čija je razina investiranja kumulativno jednaka, no godišnji trošak amortizacije se razlikuje

**Figure 3**
Annual depreciation costs for energy entities whose levels of investment are cumulatively equal but whose annual depreciation costs differ

Iako su prilikom razmatranja dva različita regulatorna pristupa korišteni poprilično jednostavni primjeri kroz koje su predočene različitosti u pristupima, primjeri odražavaju da se ulaganja trebaju razmatrati kroz duži vremenski rok. Na taj način može se provesti dosljedna regulatorna politika, ne samo u smislu utvrđivanja opravdane razine učinkovitosti, već i u smislu postizanja kontinuiranih

Although two fairly simple examples were used in analyzing the two different regulatory approaches, through which the differences in the approaches were presented, the examples demonstrate that investments must be analyzed over a long period of time. In this manner, it is possible to implement a consistent regulatory policy, not only in the sense of determining the justified level of efficiency but also

reguliranih cijena. Stabilna razina reguliranih cijena bez većih fluktuacija ne može se postići ukoliko su moguće česte promjene cijena usluga kao što je to slučaj s hrvatskim regulatornim okvirom, koji razmatra troškove subjekata koji obavljaju regulirane djelatnosti godinu za godinu. Naime, iako energetski subjekti nastoje, dugoročno gledajući, održavati istu razinu investicija na godišnjoj razini, njihovi troškovi su različiti od godine do godine, a time i razina dozvoljenog prihoda. Pitanje je na koji način će se HERA postaviti prema ovakvom problemu s kojim se susreću regulatorna tijela.

## 4 ULOGA HRVATSKE ENERGETSKE REGULATORNE AGENCIJE U DONOŠENJU PLANOVA RAZVOJA I IZGRADNJE

### 4.1 Zakonodavno rješenje

Hrvatski zakonodavac propisao je Zakonom o tržištu električne energije [8] da HEP OPS i HEP ODS donose planove razvoja i izgradnje za razdoblje od tri godine uz prethodnu suglasnost HERA-e na prijedlog planova. Međutim, zakonodavac ne prepoznaje nadležnost HERA-e u davanju suglasnosti za planove razvoja i izgradnje djelatnosti proizvodnje i opskrbe električnom energijom za tarifne kupce. Primjenjujući ovakvo zakonsko rješenje postavlja se pitanje na koji način će HERA razmatrati investicijske planove subjekata za proizvodnju i opskrbu električne energije i uključiti opravdana ulaganja u regulatornu osnovicu sredstava, budući da na njih temeljem Zakona [8] ne daje suglasnost, a primjenjuje istu metodu regulacije kao kod monopolnih djelatnosti – metoda priznatog troška. Ono što je potrebno napomenuti je da su tarifni sustavi, koje je donijela HERA, a ne zakonodavac, ulogu HERA-e u davanju suglasnosti na planove razvoja i izgradnje definirali kao identičnu za sve djelatnosti, iako to nije u skladu sa zakonskim odredbama. Nadalje, u tekstu svih tarifnih sustava navodi se da HERA daje suglasnost i na planove poslovanja svih djelatnosti iako pojam plan poslovanja Zakon [8] isto tako ne prepoznaje.

Takva razlika nadležnosti između zakonskih odredaba koje je utvrdio Hrvatski sabor i odredaba koje proizlaze iz podzakonskih akata koje je donijelo samo tijelo za sebe, u ovom slučaju HERA, potencira činjenicu da se prije donošenja drugog seta energetskih zakona nije detaljno analizirala uloga i pozicija HERA-e kao regulatornog tijela u energetskom sektoru RH kao niti regulacija energetskih djelatnosti kao disciplina sa svojim značajkama.

in the sense of achieving continuously regulated prices. A stable level of regulated prices without wide fluctuations cannot be achieved if it is possible to change the prices for services frequently, as is the case with the Croatian regulatory framework, which considers the expenditures of the entities performing regulated activities from year to year. Although the energy entities attempt to maintain the same level of investment on the annual level, viewed over the long-term, their costs differ from year to year and therefore the level of allowed revenue also differs. It is a question how the CERA will address this problem.

## 4 THE ROLE OF THE CROATIAN ENERGY REGULATORY AGENCY IN THE ADOPTION OF DEVELOPMENT AND CONSTRUCTION PLANS

### 4.1 Legislative solution

Croatian legislation stipulates that pursuant to the Electricity Market Act [8], the transmission system operator and the distribution system operator shall adopt development and construction plans for periods of three years, pending prior approval of the proposed plans by the CERA. However, the legislation does not recognize the authority of the CERA in issuing approval for the development and construction plans for the activities of the production and supply of electrical energy for tariff customers. Applying such a legal solution, the question arises concerning how the CERA will analyze the investment plans of the entities for the generation and supply of electrical energy and include the justified investment in the regulatory asset base, since according to the Law [8] it does not issue approval and applies the same method of regulation as for monopoly activities – the regulation of the rate of return. It should be mentioned that in the tariff systems which the CERA has adopted, and not the legislator, the roles of the CERA in issuing approval for development and construction plans are defined as identical for all activities, although this is not pursuant to the legal provisions. Furthermore, in the text of all the tariff systems, it is stated that the CERA also issues approval for the business plans of all activities, although the Law does not recognize the concept of a business plan [8].

Such differences in the specified authority between the legal provisions established by the Croatian Parliament and the provisions ensuing from the bylaws that the agency has issued for itself, in this case the CERA, emphasize the fact that the role

Naime, bitno je napomenuti da je HERA osnovana od strane RH kao javna ustanova što znači da joj je temeljem Zakona o ustanovama moguće dodijeliti javne ovlasti, odnosno prenijeti (delegirati) nadležnosti s državnog tijela [13]. Podjeljivanje javnih ovlasti uvijek otvara složeno pitanje smanjuje li se takvim ponašanjem opseg autoritativnog istupa države ili se pak ukupnost autoritativnog postupanja, a to znači i mogućnost uporabe prisile, proširuje. Bez obzira kojoj se konstataciji priklonili, mora se respektirati činjenica da je Zakon o ustanovama propisao da se zakonom ili na temelju zakona donesenom posebnom odlukom može javnoj ustanovi povjeriti da u sklopu djelatnosti radi koje je osnovana općim aktima uređuje određene odnose, da rješava u pojedinim upravnim stvarima o pravima, obvezama i odgovornosti fizičkih i pravnih osoba te da obavlja druge javne ovlasti.

Karakteristično je, također, da je Zakon o sustavu državne uprave, uz svoj temeljni pristup da poslove državne uprave obavljaju tijela državne uprave, propisao da se posebnim zakonom mogu određeni poslovi državne uprave prenijeti i pravnim osobama koje na temelju zakona imaju javne ovlasti [13]. Na temelju ovlasti iz posebnog zakona javne ustanove mogu obavljati najrazličitije poslove iz nadležnosti državnih tijela (posebno tijela državne uprave). Kad se razmotre odredbe Zakona o ustanovama, onda je vidljivo da je Zakon u složenom problemu podjeljivanja javnih ovlasti definirao dvoje:

- pravnu osnovu (izvor) javnih ovlasti – to su zakon, odnosno na temelju zakona donesena odluka predstavničkog tijela jedinica lokalne, područne samouprave,
- sadržaj javnih ovlasti – to je pravo da se općim aktima uređuju određeni odnosi, da se rješava u pojedinačnim upravnim stvarima o pravima, obvezama i odgovornosti određenih subjekata kao i eventualno pravo na obavljanje drugih javnih ovlasti.

Povjeravanje javnih ovlasti javnoj ustanovi znači za nju i određene dužnosti. U djelovanju javne ustanove ostvarivanje njezine posebne uloge (posebnog statusa) realizira se korištenjem javnih ovlasti i izvršavanjem dužnosti koje su joj u svezi s time nametnute. Javna ustanova mora obavljati javne ovlasti samo pod uvjetima, na način i u postupku koji je određen zakonom. Dakle, nemoguće joj je podzakonskim aktima dodjeljivati nadležnosti koje joj zakonski nisu pripisane kao što je to slučaj s pojedinim podzakonskim aktima proizašlim iz energetskih zakona.

and position of the CERA as a regulatory body within the energy sector of the Republic of Croatia and the regulation of energy activities as a discipline with specific characteristics had not been analyzed in detail prior to the adoption of the second set of energy acts. It is important to mention that the CERA was established by the Republic of Croatia as a public institution, which means that pursuant to the Institution Act it can be assigned public authority, i.e. delegated authority from the state entity [13]. The assignment of public authority always raises the complex question of whether the authority of the state is thereby diminished or whether the total authority, which means the option of the use of force, is expanded. In any case, it is necessary to respect the fact that the Institute Act stipulates that according to the law or pursuant to a law adopted by a special decision, a public institution may be entrusted, within the framework of the activities for which it has been established by enactments, to determine specific relationships; to resolve individual administrative issues about the rights, obligations and responsibilities of natural and legal persons; and to exercise other public authority.

It is also characteristic that the State Administrative System Act, in addition to the fundamental approach that the duties of state administration are to be performed by state administrative bodies, stipulates that pursuant to special legislation it is possible for specific duties of the state administration to be transferred to legal persons who have public authority pursuant to the law [13]. Therefore, based upon authorization from special legislation, public institutions are allowed to perform the most varied activities from the areas of the authority of the state bodies (especially state administrative bodies). When the provisions of the Institution Act are examined, it is evident that the Act has defined two issues within the complex problem of the assignment of public authority:

- the legal basis (source) of public authority – i.e. a ruling adopted pursuant to the law by the representative agency of the units of local and regional self-management,
- the content of public authority – i.e. the right to use enactments to determine relationships, to resolve issues concerning the rights, obligations and responsibilities of specific entities in individual administrative matters, as well as the eventual right to exercise other public authority.

The entrusting of public authority to a public institution means that specific duties are entrusted to it. In the operations of a public institution, it exercises its specific role (special status) through the exercise of public authority and the performance of duties that

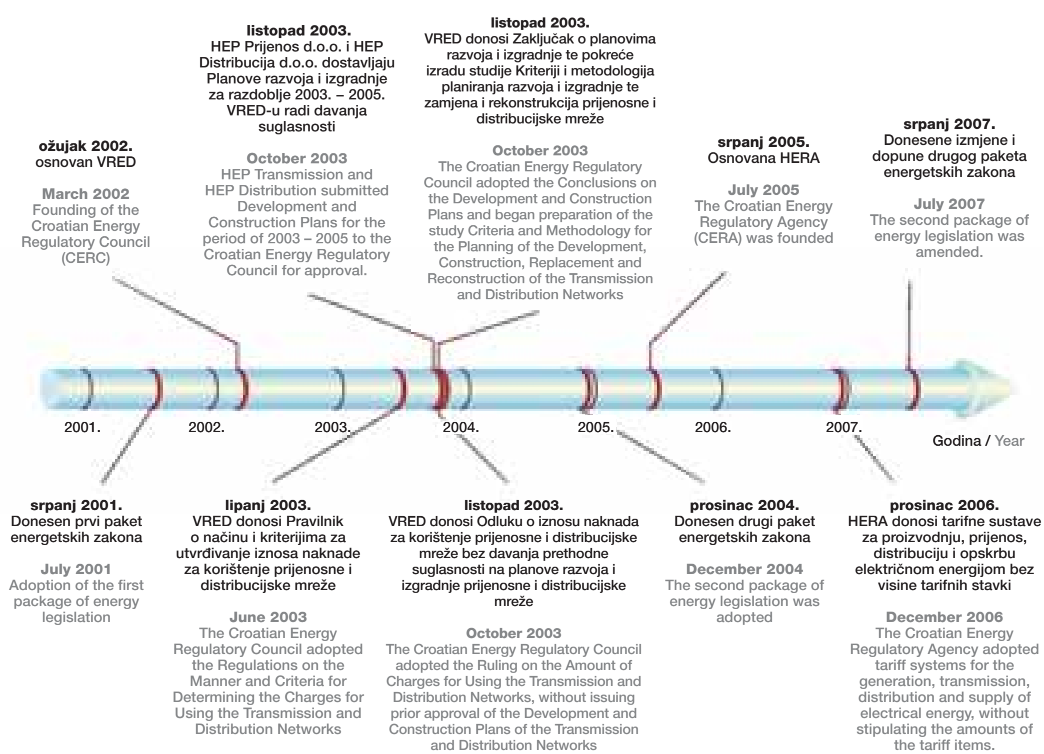
## 4.2 Kriteriji za davanje suglasnosti na planove razvoja i izgradnje reguliranih energetskih subjekata

Energetski subjekti na koje se doneseni tarifni sustavi odnose nisu još dostavili HERA-i planove poslovanja, razvoja i izgradnje (koliko je poznato autorima) radi davanja suglasnosti. Rok za dostavu planova je 30. studenoga što proizlazi iz odredbi tarifnih sustava. Stoga se u ovom trenutku ne može razmatrati HERA-in odnos prema davanju suglasnosti na planove razvoja i izgradnje te koliko duboko je HERA spremna analizirati kriterije za odabir pojedinih investicija kao i da li će ući u analizu tehničkih rješenja ili će se povesti samo za odlukama energetskih subjekata kao instanci meritornih za definiranje kriterija od HERA-e. Isto tako ne može se razmatrati na koji način će HERA pristupiti utvrđivanju opravdanih, može se reći i učinkovitih, razina pojedinih troškova, te koje investicije će priznati u regulatornoj osnovici sredstava.

are thereby assigned to it. A public institution must exercise public authority only under the conditions, in such a manner and according to the procedure stipulated for it according to law. Therefore, it is not possible for enactments to assign authorization not stipulated by law, such as in the case of individual enactments resulting from energy legislation.

## 4.2 Criteria for issuing approval for the development and construction plans of entities performing regulated activities

The energy subjects to which the adopted tariff systems refer have still not submitted their plans for operations, development and construction (to the best of the authors' knowledge) to the CERA for approval. The deadline for the submission of the plans is November 30, according to the provisions of the tariff systems. Therefore, at this moment it is not possible to discuss the CERA's attitude toward issuing approval for development and construction plans and how deeply the CERA is prepared to analyze the criteria for choosing individual investments, as well as whether it will enter into analysis of the technical solutions itself or rely solely upon the decisions of the energy entities as sufficiently authoritative for defining its criteria. Similarly, it is not possible to discuss how the CERA will approach the determination of justified, it can be said effective, levels of individual expenditures, and which investments it will recognize in the regulatory asset base.




**Slika 4**
Vremenski tijek donošenja propisa koji su vezani uz ulogu regulatornog tijela (VRED/HERA) u davanju suglasnosti na planove razvoja i izgradnje prijenosne i distribucijske mreže

**Figure 4**
Time line of regulations adopted in connection with the role oh the regulatory body (CERC/CERA) in approving the development and construction plans of the transmission and distribution networks

**4.2.1** Iskustva Vijeća za regulaciju energetskih djelatnosti

Zakon o tržištu električne energije iz 2001. godine također je definirao da tadašnje regulatorno tijelo, Vijeće za regulaciju energetskih djelatnosti (VRED) [14], daje prethodnu suglasnost na plan razvoja i izgradnje prijenosne i distribucijske mreže. Hrvatski nezavisni operator sustava i tržišta d.o.o. (HNOSIT d.o.o.) i HEP Prijenos d.o.o. u 2003. godini proslijedili su Plan razvoja i izgradnje prijenosne mreže za razdoblje od 2003. do 2005. godine, odnosno HEP Distribucija d.o.o. Plan razvoja i izgradnje distribucijske mreže za razdoblje od 2003. do 2005. godine, VRED-u radi davanja prethodne suglasnosti. Budući da prije toga VRED nije zauzeo stav prema načinu na koji će pristupiti davanju prethodne suglasnosti na planove, VRED je pokrenuo izradu Kriterija i metodologija planiranja razvoja i izgradnje te zamjena i rekonstrukcija prijenosne i distribucijske mreže kojima se nastojalo na razvidan, jasan i dosljedan način utvrditi polazno stajalište regulatornog tijela vis-á-vis strategije razvoja prijenosne i distribucijske mreže kao i kriterija za rekonstrukciju postojećih objekata. Imajući u vidu da rad regulatornog tijela treba počivati na načelima razvidnosti, dosljednosti i stručnosti, VRED je zauzeo stajalište da je energetskom subjektu potrebno jasno definirati što se od njega očekuje tako da i buduća stajališta, odnosno odluke regulatornog tijela budu na svojevrstan način predvidljive. Tim više ukoliko se radi o kapitalno intenzivnim djelatnostima za čija ulaganja su potrebne dugoročnije analize kao i srednjoročan, odnosno dugoročan povrat investicijskih sredstava, koji se ujedno odražava i u iznosu tarifnih stavki.

Ilustrativni primjer VRED-ovog Zaključka iz 2003. godine koje je bilo ishodište za izradu Kriterija i metodologija planiranja razvoja i izgradnje te zamjena i rekonstrukcija prijenosne mreže, odnosno pokretanje dorade dostavljenog Plana razvoja i izgradnje prijenosne mreže za razdoblje od 2003. do 2005. godine, je sljedeći [15]:

I. Plan je potrebno donijeti u skladu sa Strategijom energetskog razvitka i Programom provedbe Strategije energetskog razvitka,

II. Da bi se provela procedura ocjene Plana i davanja suglasnosti na prijedlog Plana propisane člankom 12. stavak 1. Zakona o tržištu električne energije [14] potrebno je ispuniti sljedeće uvjete:

   1) definirati kriterije i metodologiju planiranja razvoja prijenosne mreže kao i metodologiju plana zamjene i rekonstrukcije koje će uključivati i ekonomske kriterije planiranja,

**4.2.1** Experience of the Croatian Energy Regulatory Council

The Electricity Market Act of 2001 also stipulated that the regulatory body at the time, the Croatian Energy Regulatory Council – CERC (Vijeće za regulaciju energetskih djelatnosti – VRED) [14], would issue prior approval for the development and construction plans of the transmission and distribution networks. In the year 2003, the Croatian Independent System and Market Operator – CISMO (Hrvatski nezavisni operator sustava i tržišta d.o.o. – HNOSIT d.o.o.) and HEP Transmission (HEP Prijenos d.o.o.) forwarded the Development and Construction Plan for the Transmission Network for the Period of 2003 to 2005, and HEP Distribution (HEP Distribucija d.o.o.) forwarded the Development and Construction Plan for the Distribution Network for the Period of 2003 to 2005 to the Croatian Energy Regulatory Council – CERC in order to obtain prior approval. Since the CERC had not previously taken a position regarding the manner in which it would approach the issue of prior approval for plans, it started work on the Criteria and Methodology for Planning the Development, Construction, Replacement and Reconstruction of Transmission and Distribution Networks, by which it attempted to determine the starting position of the regulatory body vis-à-vis the strategic development of the transmission and distribution networks as well as the criteria for the reconstruction of the existing facilities in a transparent, clear and consistent manner. Bearing in mind that the work of the regulatory body should be based upon the principles of transparency, consistency and expertise, the CERC assumed the position that it is necessary to provide a clear definition to the energy entity concerning what is expected of it so that the future positions, i.e. decisions, of the regulatory body would be predictable. This is even more important regarding investments in capital intensive activities, which would require long-term as well as medium-term analysis, i.e. the long-term return of invested assets, as also reflected in the amount of the tariff items.

An illustrative example of the CERC's conclusion from the year 2003, which was the starting point for devising the Criteria and Methodologies for Planning the Development, Construction, Replacement and Reconstruction of the Transmission Network, as well as preparing the final modifications of the submitted Development and Construction Plan for the Transmission Network for the Period from 2003 to 2005, is as follows [15]:

I. The plan must be adopted, pursuant to the Strategy for Energy Development and the Program for the Implementation of the Strategy for Energy Development,

što je u skladu s prijedlogom Mrežnih pravila hrvatskog elektroenergetskog sustava (koja u trenutku donošenja Zaključka nisu bila usvojena), a u kojima se takav kriterij jednoznačno ne definira,
2) planirati izgradnju objekata te zamjenu i rekonstrukcije objekata na način da predviđeni objekti zadovoljavaju definirane kriterije,
3) iskazati troškove HNOSIT-a d.o.o. odvojeno od planova HEP Prijenos d.o.o. te ih procijeniti u skladu s ulogom koju HNOSIT d.o.o. preuzima prema Zakonu o tržištu električne energije,

III. U daljnjim koracima potrebno je započeti sa sljedećim radnjama:

1) definirati zahtjeve koji se postavljaju na prijenosnu mrežu prvenstveno u smislu kvalitete električne energije isporučene izravnim i distributivnim kupcima (frekvencija, napon, raspoloživost mreže), te s obzirom na strateška pitanja razvoja mreže (samodostatnost, tretman susjednih mreža u planiranju, tranziti i uloga mreže u tržištu električne energije, izgradnja novih interkonekcija, modernizacija sustava, kriteriji izgradnje GIS postrojenja i dr.),
2) formirati jedinstvenu bazu podataka nužnu za planiranje razvoja mreže te definirati neke osnovne ulazne podatke bitne kod planiranja poput jediničnih troškova neisporučene električne energije, jediničnih cijena visokonaponske opreme, diskontne stope za potrebe planiranja i dr.,
3) za svaki objekt predviđen za izgradnju ili zamjenu i rekonstrukciju izraditi tehnoekonomski elaborat iz kojeg bi proizašlo da li razmatrani objekt zadovoljava kriterije planiranja definirane Mrežnim pravilima i ostalim pripadnim dokumentima.

Zaključak sličnog karaktera VRED je donio i prilikom ocjene Plana razvoja i izgradnje distribucijske mreže za razdoblje od 2003. do 2005. godine. Na istoj sjednici VRED-a na kojoj je VRED donio navedene Zaključke, VRED je donio Odluku o iznosu naknada za korištenje prijenosne i distribucijske mreže [16] temeljem Zakona o tržištu električne energije iz 2001. godine [14]. Ta Odluka još uvijek je na snazi budući da je tarifni sustavi koje je donijela HERA nisu stavili van snage. Slika 4 prikazuje tijek donošenja relevantnih propisa i odluka koji se odnose na ulogu hrvatskog regulatornog tijela HERA-e, odnosno VRED-a, u donošenju planova razvoja i izgradnje prijenosne i distribucijske mreže.

II. In order to implement the procedures for the evaluation of the Plan and the issue of approval for the proposed Plan stipulated in Article 12, Paragraph 1 of the Electricity Market Act [14], the following prerequisites must be met:

1) to define the criteria and methodology for the planning of the development of the transmission network as well as the methodology for the replacement and reconstruction plan, which will include the economic criteria for planning, pursuant to the proposed Grid Code of the Croatian Electrical Energy System (which at the time of the adoption of the conclusion had still not been adopted), and in which such criteria are not defined unambiguously,
2) to plan the construction of facilities and the replacement and reconstruction of facilities in such a manner that the facilities meet the defined criteria,
3) to present the expenditures of the Croatian Independent System and Market Operator – CISMO (HNOSIT d.o.o.) separately from the plans of HEP Transmission (HEP – Prijenos d.o.o.) and to evaluate them according to the role that the CISMO assumes according to the Electricity Market Act,

III. In subsequent steps, it is necessary to begin the following activities:

1) to define the requirements that are established for the transmission network, primarily in the sense of the quality of the electrical energy to direct customers and customers connected to the distribution network (frequency, voltage and network availability), and regarding the strategic question of network development (self-sufficiency, the treatment of neighboring networks in planning; transit and the role of networks in the electrical energy market, the construction of new interconnections, the modernization of the system, the criteria for the construction of Geographical Information System [GIS] facilities etc.),
2) to establish a unified database necessary for the planning of network development and to define some basic input data required for planning, such as the unit prices of undelivered electrical energy, unit prices of high-voltage equipment, discount rates for the necessary planning etc.,
3) for each facility planned for construction, replacement or reconstruction, to prepare a technical/economic study which would show whether said facility meets the planning criteria defined by the Grid Code and other relevant documents.

### 4.2.2 Iskustva Hrvatske energetske regulatorne agencije

HERA za sada nije pristupila izradi sličnih kriterija ili stajališta o planovima razvoja i izgradnje HEP OPS-a i HEP ODS-a, niti je utvrdila svoj stav prema dubini analize (prema javno dostupnim informacijama). Nepostojanje unaprijed definiranih kriterija za davanje suglasnosti na planove moglo bi dodatno odgoditi donošenje iznosa tarifnih stavki za pojedine djelatnosti, budući da je davanje suglasnosti na planove preduvjet je za davanje mišljenja na prijedlog iznosa tarifnih stavki koje energetski subjekt dostavlja Ministarstvu gospodarstva, rada i poduzetništva (MINGORP), a MINGORP prosljeđuje HERA-i na mišljenje.

### 4.3 Stavovi Hrvatske energetske regulatorne agencije u rješavanju preduvjeta za primjenu metode priznatih troškova

Iz prethodno iznesene rasprave vezano uz regulatorni pristup gradnje blokova i regulatorni pristup ukupnih troškova vidljivo je da je vrlo značajna uloga regulatornoga tijela u utvrđivanju opravdane razine pojedinih regulatornih parametara. Utvrđena metoda priznatih troškova u donesenim tarifnim sustavima prepoznaje regulatorne parametre koji su ranije analizirani kao što su to – regulatorna osnovica sredstava, amortizacija i stopa povrata u vidu ponderiranog prosječnog troška kapitala. Tarifni sustavi definiraju da mišljenje o priznatim troškovima poslovanja (*OPEX*) i stopi povrata kapitala daje HERA, dok se kapitalni troškovi (*CAPEX*) – regulirana osnovica sredstava, tj. prinos od regulirane imovine i amortizacija utvrđuju na osnovi planova razvoja i izgradnje na koje HERA daje suglasnost. Utvrđena metoda regulacije ne poznaje faktor učinkovitosti kao regulatorni parametar metode.

Osim stava o dubini uplitanja u elemente planova poslovanja, razvoja i izgradnje, HERA bi trebala po mišljenju autora prilikom postupka davanja mišljenja na prijedlog iznosa tarifnih stavki po djelatnostima, između ostalog, svoj stav zauzeti i o sljedećem:

- je li obavljen razvidan i dosljedan nadzor nad razdvajanjem djelatnosti kako u tehničkom i tako i financijskom pogledu,
- opravdanoj razini stope povrata za svaku pojedinu djelatnost,
- koje investicije uključiti u regulatornu osnovicu sredstava, što uključuje i tumačenje pojedinih pojmova iz tarifnih sustava, kao što je npr. pojam nove investicije koje su sufinancirane, a uključene su u regulatornu osnovicu sredstava,
- opravdanoj razini troškova poslovanja (*OPEX*),
- i slično.

The CERC also adopted a conclusion of a similar character in the evaluation of the Development and Construction Plan for the Distribution Network for the Period from 2003 to 2005. At the same CERC session, at which the CERC adopted the previously mentioned conclusions, it also adopted the Decision on Fees for Using the Transmission and Distribution Networks [16], pursuant to the Electricity Market Act of 2001 [14]. This Decision is still in force, since the tariff systems that the CERA adopted are still in force. Figure 4 shows the course of the adoption of the relevant regulations and decisions that refer to the role of the Croatian Energy Regulatory Agency – CERA or the Croatian Energy Regulatory Council – CERC, in the adoption of development and construction plans for the transmission and distribution networks.

### 4.2.2 Experience of the Croatian Energy Regulatory Agency

For the present, the CERA has not started to develop similar criteria or positions on the development and construction plans of the transmission system operator and the distribution system operator, and has not defined its position toward in-depth analysis. The lack of previously defined criteria for issuing approval for plans could additionally postpone the adoption of the amounts of the tariff items for individual activities, since the issuing of approval for the plans is a prerequisite for issuing an opinion on the proposed amounts of the tariff items which an energy entity submits to the Ministry of the Economy, Labor and Entrepreneurship, and which the Ministry forwards to the CERA for an opinion.

### 4.3 Positions of the Croatian Energy Regulatory Agency in resolving the prerequisites for the application of the rate of return (*RoR*) method

From the previous discussion of the building block regulatory approach and the total expenditure regulatory approach, it is evident that the regulatory body has a highly significant role in the determination of the justified levels of individual regulatory parameters. The rate of return method in the adopted tariff systems recognizes the regulatory parameters that were analyzed previously, such as the regulatory asset base (*RAB*), depreciation and the rate of return regarding the weighted average cost of capital (*WACC*). The tariff systems stipulate that an opinion on the recognized operating expenditure (*OPEX*) and the rate of return on capital shall be issued by the CERA, while the capital expenditure (*CAPEX*) – the regulatory asset base, i.e. the revenue from regulated assets and depreciation shall be determined on the basis of the development and construction plans which shall be approved by the CERA. The established method of regulation does not recognize the efficiency factor as a regulatory parameter.

Jedan od bitnih preduvjeta za mogućnost uvođenja metode regulacije kao što je to metoda priznatih troškova je provođenje razvidnog i dosljednog razdvajanja djelatnosti u punom smislu – od razdvajanja imovine, osoblja do pridjeljivanja potraživanja po kreditima i sl. Jedan od problema je na koji način će HERA pristupiti davanju mišljenja na iznos tarifnih stavki za opskrbu električnom energijom ukoliko se zna da se nisu razdvojile djelatnosti distribucije i opskrbe električnom energijom te da HEP Operator distribucijskog sustava d.o.o. obavlja uz djelatnost distribucije i opskrbu električnom energijom, iako je zakonski rok za razdvajanje istih istekao (1. srpnja 2007. godine) [8].

Isti problem preslikava se i na utvrđivanje opravdane razine *OPEX*-a koji bi se trebao utvrditi na razini koja odražava učinkovitost poslovanja ili barem bi se ta razina tijekom godina trebala približiti učinkovitoj razini koja bi vrijedila da se djelatnost izloži tržišnom natjecanju i rizicima. Između ostalog, postavlja se pitanje što predstavlja *OPEX* u slučaju HEP Opskrbe d.o.o. koja obavlja djelatnost opskrbe samo za povlaštene kupce. Znači, taj trošak tarifni kupci uopće ne bi trebali snositi. Sa stajališta regulatornog tijela koje, uz zaštitu održivog poslovanja energetskog subjekta i omogućavanje nenarušenog tržišnog natjecanja, ima zadatak zaštite kupaca, bilo bi neopravdano priznati taj trošak kroz primjenu metode priznatih troškova i davanja pozitivnog mišljenja na prijedlog iznosa tarifnih stavki koji uključuju trenutačni trošak alociran unutar HEP Grupe na HEP Opskrbu d.o.o.

Nadalje, provedba razvidnog razdvajanja ima utjecaja i na *CAPEX* u svim djelatnostima. Naime, za svaku djelatnost HERA bi trebala utvrditi opravdanu razinu početne regulatorne osnovice sredstava, zatim amortizacijsku politiku i sredstva koja se tijekom regulatornog razdoblja dodjeljuju regulatornoj osnovi sredstva na koju se primjenjuje stopa povrata na kapital. Stopu koja se primjenjuje na srednju vrijednost regulatorne osnovice sredstava utvrđuje HERA na prijedlog energetskog subjekta. Problem koji se ovdje javlja je i utvrđivanje opravdane stope povrata, budući da se radi o djelatnostima koje su po svom karakteru različite – monopolne i tržišne, iz čega proizlaze različiti stupnjevi rizika u poslovanju kao i različiti uvjeti financiranja. Naime, iz opisa metode navedene u tarifnim sustavima nije razvidno koja će se stopa primijeniti i hoće li se ona razlikovati po djelatnostima, iako se radi o istom vertikalno organiziranom poduzeću HEP Grupi. Utvrđivanje stope povrata zahtijeva provođenje detaljnih analiza koje HERA još nije provela. Da bi HERA-in rad dobio na vjerodostojnosti i stručnosti potrebno je da HERA pravodobno, prije donošenje odluka i pod-

In addition to the position on the depth of involvement in the elements of the business, development and construction plans, it is the authors' opinion that the CERA should take a position on the following matters when issuing opinions on the proposed tariff amounts according to activities:

- whether transparent and consistent supervision has been performed over the unbundling of the technical and financial activities,
- the justified level of the rate of return for each individual activity,
- which investments should be included in the regulatory asset base, together with the interpretation of individual concepts from the tariff systems, such as, for example the concept of new investments that are co-financed and included in the regulatory asset base,
- the justified level of operating expenditures (*OPEX*),
- etc.

One of the essential prerequisites for the possible introduction of regulatory methods such as the rate of return method is the transparent and consistent unbundling of activities in the full sense – including the unbundling of assets, personnel, claims on loans etc. One of the problems is how the CERA will approach the issuing of opinions on the amount of tariff items for the supply of electrical energy if it knows that the activities of the distribution and supply of electrical energy have still not been unbundled and that the HEP Distribution System Operator performs the activity of the supply of electrical energy in addition to the activity of the distribution of electrical energy.

The same problem is also reflected in the determination of the justified level of *OPEX*, which should be determined at a level that reflects the efficiency of operations or at least this level during the year should approach a efficiency level that would be valid if the activity were subject to market competition and risks. Thus, among other things, the question is posed what *OPEX* represents in the case of HEP Supply (HEP Opskrba d.o.o.), which only performs the activity of supply for eligible customers. This means that tariff customers should not have to cover this expenditure. From the standpoint of the regulatory body which, in addition to safeguarding the sustainable operations of the energy entity and facilitating inviolable market competition, also has the task of protecting the customers, it would be unjustified to recognize this expenditure through the application of the rate of return method and issue a positive opinion on the proposed amounts of tariff items, which include the current expenditure allocated within the HEP Group for HEP Supply.

zakonskih akata, provede sve nužne analize koje u slučaju utvrđivanja metoda za izračun cijena usluga ponekad (po iskustvima drugih regulatornih tijela) traju i po 18 mjeseci [6].

Osim stope povrata, kod *CAPEX* -a, dilemu predstavlja tumačenje i drugih pojmova koje prepoznaje tarifni sustav, a isti nisu u dovoljnoj mjeri pojašnjeni, npr. vrijednost novih investicija koje su sufinancirane. Pretpostavlja se da ih sufinancira kupac. Trošak investicije koji je financirao kupac ne bi trebao ući u regulatornu osnovicu sredstava niti biti priznat kroz trošak amortizacije energetskog subjekta, budući da bi na taj način kupac plaćao investiciju dva puta – kroz trošak investicije i kroz tarifu. Upitno je na koji način će HERA pristupiti rješavanju problema investicija koje sufinancira kupac.

Navedeni primjeri pitanja na koje HERA mora odgovoriti prilikom davanja mišljenja na prijedlog iznosa tarifa i provođenja regulatorne politike samo su ilustrativni. Primjena ekonomske regulacije seže puno dublje i kompleksnija je od navedenih primjera te zahtijeva detaljne elaboracije i analize. No, i argumentirani stavovi koje HERA treba zauzeti prilikom rješavanja navedenih dilema iz opisanog primjera mogu značajno utjecati na razinu tarifnih stavki pojedinih djelatnosti te na raspodjelu troškova i prihoda između djelatnosti.

Furthermore, transparent division also has an impact on *CAPEX* in all activities. For each activity, the CERA would have to determine the justified level of the initial regulatory asset base, the depreciation policy and the assets that would be allocated to the regulatory asset base during the regulatory period, to which the rate of return on capital would be applied. The rate that is applied to the mean value of the regulatory asset base is determined by the CERA at the proposal of the energy entity. A problem that occurs here is the determination of the justified rate of return, since this concerns activities that differ in nature – monopolistic and market, from which there are different degrees of risks in operations as well as different conditions of financing. From the description of the methods stated in the tariff systems, it is not clear which rate will be applied and whether the rates will differ according to activities, although they concern the same vertically organized enterprise in the HEP Group. Determination of the rate of return requires detailed analysis. In order for the CERA's work to obtain credibility and professionalism, prior to adopting decisions and regulations the CERA must first perform all the necessary analyses in a timely manner, which in the case of the determination of the methods for the calculation of the prices for services sometimes (according to the experiences of other regulatory bodies) requires as long as 18 months [6].

In addition to the rate of return, regarding *CAPEX* there is a dilemma posed by the interpretation of other concepts that the tariff system recognizes, which are not explained to a sufficient extent, such as the value of new investments that are co-financed. It is assumed that they are co-financed by the customer. An investment expenditure that a customer has financed should not enter the regulatory asset base or be recognized as a depreciation expenditure of the energy entity. Otherwise, the customer would have to pay for the investment twice – through the investment expenditure and through the tariff. Therefore, it is a question how the CERA will approach the solution of the problem of investments that are co-financed by the customer.

The cited examples of questions to which the CERA must respond when issuing an opinion on the proposed amounts of tariffs and the implementation of regulatory policies are merely illustrative. The application of economic regulations ranges far deeper, is much more complex than the examples presented and requires more detailed elaboration and analysis. However, the argued positions that the CERA should assume when resolving the cited dilemmas from the example described could significantly affect the level of the tariff items for individual activities and the allocation of expenditures and revenues among the activities.

## 5 ZAKLJUČAK

U utvrđivanju reguliranih cijena primjenjuju se različite metode ekonomske regulacije i to prvenstveno u djelatnostima koje su po svom karakteru monopolne, znači prijenosu i distribuciji električne energije, a ne u djelatnostima proizvodnje i opskrbe koje su po svom karakteru tržišne djelatnosti. Sukladno tome, regulatorno tijelo u većini analiziranih država donosi ili daje suglasnost na planove razvoja i izgradnje monopolnih djelatnosti kao preduvjet za utvrđivanje cijena reguliranih usluga. Zakonska nadležnost regulatornog tijela da donosi ili daje suglasnost na planove razvoja i izgradnje energetskih subjekata u načelu ne daje odgovor koliko duboko je pravo regulatornog tijela da zadire u planove razvoja i izgradnje energetskih subjekata. Stoga se vrlo često u početku uvođenja regulatorne prakse postavlja pitanje koliko meritorno može biti regulatorno tijelo prilikom ulaska u rasprave o pojedinim koncepcijskim rješenjima, odnosno o pojedinim tehničkim pitanjima. Praksa u regulatornim tijelima u EU, odnosno članicama ERRA-e, s dužom regulatornom praksom od HERA-e pokazala je da su koncepcijska rješenja i kriteriji za izgradnju objekata u načelu odluka energetskog subjekta, dok regulatorno tijelo odobrava poslovne planove uključujući financijsko pokrivanje investicijskog plana. Paralelno odobravanju poslovnih planova, regulatorna tijela utvrđuju opravdanu razinu učinkovitosti te razinu kvalitete opskrbe kako se smanjenjem troškova ne bi smanjila i kvaliteta opskrbe.

Regulatorna politika može imati značajan utjecaj na budući prihod energetskog subjekta kroz utvrđivanje regulatorne osnovice sredstava u koju ulaze odobrena ulaganja te kroz utvrđeni faktor učinkovitosti. Odobrena razina ulaganja ima značajan odraz na visinu regulirane cijene koja proizlazi iz primijenjene regulatorne metode. Isto tako, ukoliko se jednom investicija prizna u *CAPEX*-u, a ne realizira se tijekom regulatornog razdoblja za koje je odobrena, nije opravdano opet uključiti je u *CAPEX* u sljedećem regulatornom razdoblju. Ako se radi o kratkom regulatornom razdoblju, kao što je to npr. jedna godina kako je predviđeno tarifnim sustavima koje je donijela HERA, postavlja se pitanje na koji način će regulatorno tijelo pratiti realizaciju investicije i njeno uključivanje u *CAPEX*. Naime, regulatorni pristupi analizirani u ovom članku pokazali su da je prilikom utvrđivanja *CAPEX*-a, odnosno razmatranja učinkovitosti pojedinog energetskog subjekta potrebno analizirati troškove kroz duže vremensko razdoblje. Takvom analizom, odnosno primjenom metoda ravnanja po mjerilu na složenijem skupu podataka, osigurala bi se vjerodostojnost i razvidnost postupanja regu-

## 5 CONCLUSION

In the determination of regulated prices, various methods of economic regulation are applied, primarily to activities that are by their nature monopolistic, i.e. the transmission and distribution of electrical energy, and not to the activities of generation and supply, which are by their nature market activities. Consequently, the regulatory bodies in the majority of the countries analyzed adopt or issue approval for the development and construction plans of monopolistic activities as a prerequisite for the determination of the prices for regulated services. The legal authority of a regulatory body to adopt or issue approval for the development and construction plans of energy entities in principle does not provide an answer to how much of a right the regulatory body has to interfere in the development and construction plans of energy entities. Therefore, the question is very often posed at the beginning of the introduction of regulatory practices concerning how competent a regulatory body can be when entering into a discussion on individual conceptual solutions, i.e. individual technical questions. The practice of the regulatory bodies in the EU or the members of the ERRA, with longer regulatory experience than the CERA, has shown that conceptual solutions and criteria for the construction of facilities are in principle the decision of the energy entity, while the regulatory body approves business plans including the financial coverage of the investment plan. Parallel to approving business plans, the regulatory body determines the justified level of efficiency and the level of the quality of supply, so that a reduction in expenditures does not lead to a reduction in the quality of the supply.

Regulatory policy can have a significant impact on the future revenue of an energy entity through the determination of the regulatory asset base in which approved investments are made and through the determination of the efficiency factor. The approved level of investment is significantly reflected in the amounts of the regulated prices determined from the application of a regulatory method. Similarly, if an investment is recognized in *CAPEX* and is not implemented during the regulatory period for which it has been approved, it is not justified to include it in *CAPEX* again for the subsequent regulatory period. If the regulatory period is short, such as, for example, one year, the question is posed how the regulatory body will monitor the implementation of the investment and its inclusion in *CAPEX*. The regulatory approaches analyzed in this article have demonstrated that when determining *CAPEX*, i.e. considering the efficiency of an individual energy entity, it is necessary to analyze expenditures over a long period of time. With such analysis, i.e. the application of the benchmarking method to a complex

latornog tijela tijekom procesa utvrđivanja cijena reguliranih usluga.

HERA, prilikom donošenja tarifnih sustava i opredjeljenja za metodu regulacije priznatih troškova, nije razmatrala posljedice koje regulatorni pristup može imati na dozvoljeni prihod reguliranih energetskih subjekata. Ujedno nije zauzela jasan i nedvosmislen stav prema nizu pitanja i dilema koje se mogu javiti tijekom postupka davanja suglasnosti na planove razvoja i izgradnje prijenosne i distribucijske mreže kao i tijekom davanja mišljenja na prijedlog energetskih subjekata o iznosu tarifnih stavki. Stoga je postupanje hrvatskog regulatornog tijela u postupku donošenja reguliranih cijena na temelju neke od poznatih metoda ekonomske regulacije još uvijek nedefinirano te nema dosadašnje prakse koja bi se mogla analizirati. Isto tako nepoznata je praksa HERA-e u smislu davanja suglasnosti na planove razvoja i izgradnje HEP OPS-a i HEP ODS-a.

Imajući u vidu dosadašnji tijek uvođenja ekonomske regulacije u Hrvatskoj te argumentaciju iz članka kao i iskustva drugih regulatornih tijela zaključak je autora da se zakonsko rješenje nužno mora mijenjati u više segmenata.

Prvo, da se prilikom definiranja nadležnosti HERA-e definiraju sve njene nadležnosti kroz zakonske odredbe, a ne da se naknadno iste utvrđuju kroz podzakonske akte koje donosi MINGORP ili HERA, kao što je to npr. slučaj s davanjem suglasnosti na planove poslovanja ili planove razvoja i izgradnje energetskog subjekta za proizvodnju i opskrbu električnom energijom.

Drugo, da se uloga HERA-e i primjena neke od poznatih metoda ekonomske regulacije ograniči samo na monopolne djelatnosti za koje su iste i razvijane. Naime, regulacija cijena u klasičnom smislu riječi gubi važnost u djelatnostima koje su po svom karakteru tržišne (u kojima tarifa značajno ovisi o parametrima na koje energetski subjekt ne može utjecati i koje regulatorno tijelo ne može nadzirat, kao što je to npr. cijena goriva) i u kojima regulatorno tijelo ne daje suglasnost na planove, kao što je to slučaj s proizvodnjom i opskrbom električnom energijom.

Treće, zakonsko rješenje sa samo polovično definiranim rokovima pokazalo se kao nedostatno. Naime, predviđen je rok za donošenje tarifnih sustava bez visine tarifnih stavki, a da nije predviđen rok za donošenje iznosa tarifnih stavki.

Posljedica ovakvog slijeda zakonskih rješenja je da su tarifni sustavi doneseni u prosincu 2006. godine, a da nisu prije toga napravljene simulacije

group of data, the credibility and transparency of the behavior of the regulatory body during the process of the determination of the prices for regulated services would be assured.

When adopting tariff systems and deciding upon the method for the regulation of the rate of return, the CERA did not consider the consequences that a regulatory approach can have on the allowed revenue of entities performing regulated activities. It also did not assume a clear and unambiguous position toward a series of questions and dilemmas that can arise during the procedure for the issuing of approval for the development and construction plans of the transmission and distribution networks as well as when issuing an opinion on proposals by energy entities on the amounts of tariff items. Therefore, the procedure by the Croatian Energy Regulatory Agency in the adoption of regulated prices on the basis of some of the recognized methods of economic regulation has still not been defined and there is no practical experience to date that could be analyzed. Similarly, the CERA's practices in the sense of issuing approval for development and construction plans for the transmission system operator and the distribution system operator are also unknown.

Bearing in mind the progress thus far in the introduction of economic regulation in the Republic of Croatia and the argumentation from the article, as well as the experiences of other regulatory bodies, it is the authors' conclusion that several segments of the legislative solution in the Republic of Croatia must be changed.

First, all of the CERA's authorities should be defined through legal provisions instead of determining them retrospectively through regulations issued by the Ministry of the Economy, Labor and Entrepreneurship or the CERA, such as, for example, the case of issuing approval for the business plans or the development and construction plans of an energy entity for the generation and supply of electrical energy.

Second, the role of the CERA and the application of some of the recognized methods of economic regulation should be limited to the monopolistic activities for which they were developed. Price regulation in the classical sense has diminished significance in activities with a market character (in which the tariff significantly depends upon parameters which the energy entity cannot influence and which the regulatory body cannot supervise, such as, for example, the price of fuel) and for which the regulatory body does not issue approval for plans, such as in the case of the generation and supply of electrical energy.

prihvaćene metode priznatih troškova s ulaznim podacima od HERA-e odobrenih planova razvoja i izgradnje reguliranih energetskih subjekata. Takva simulacija iznosa tarifnih stavki bi na razvidan način prikazala HERA-in stav prema priznavanju razine *OPEX*-a i *CAPEX*-a.

Third, a legal solution with only partially defined deadlines has proven to be insufficient. The deadline has been set for the adoption of tariff systems without the stipulation of the amounts of the tariff items, and the deadline for the adoption of the tariff items has not been set.

As a consequence of such a sequence of legislative solutions, the tariff systems were adopted in December 2006 without prior simulations based upon the accepted rate of return method and the input data came from development and construction plans of the entities performing regulated activities which the CERA had not previously approved. Such simulations of the amounts of the tariff items would present the CERA's position toward the recognized levels of *OPEX* and *CAPEX* in a transparent manner.

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Uredništvo primilo rukopis:
2007-08-14

Prihvaćeno:
2007-09-14

Manuscript received on:
2007–08–14

Accepted on:
2007–09–14

# NUMERIČKI PRORAČUN NISKOFREKVENCIJSKIH ELEKTROMAGNETSKIH PRIJELAZNIH POJAVA U ENERGETSKIM TRANSFORMATORIMA

# THE NUMERICAL CALCULATION OF LOW FREQUENCY ELECTROMAGNETIC TRANSIENT PHENOMENA IN POWER TRANSFORMERS

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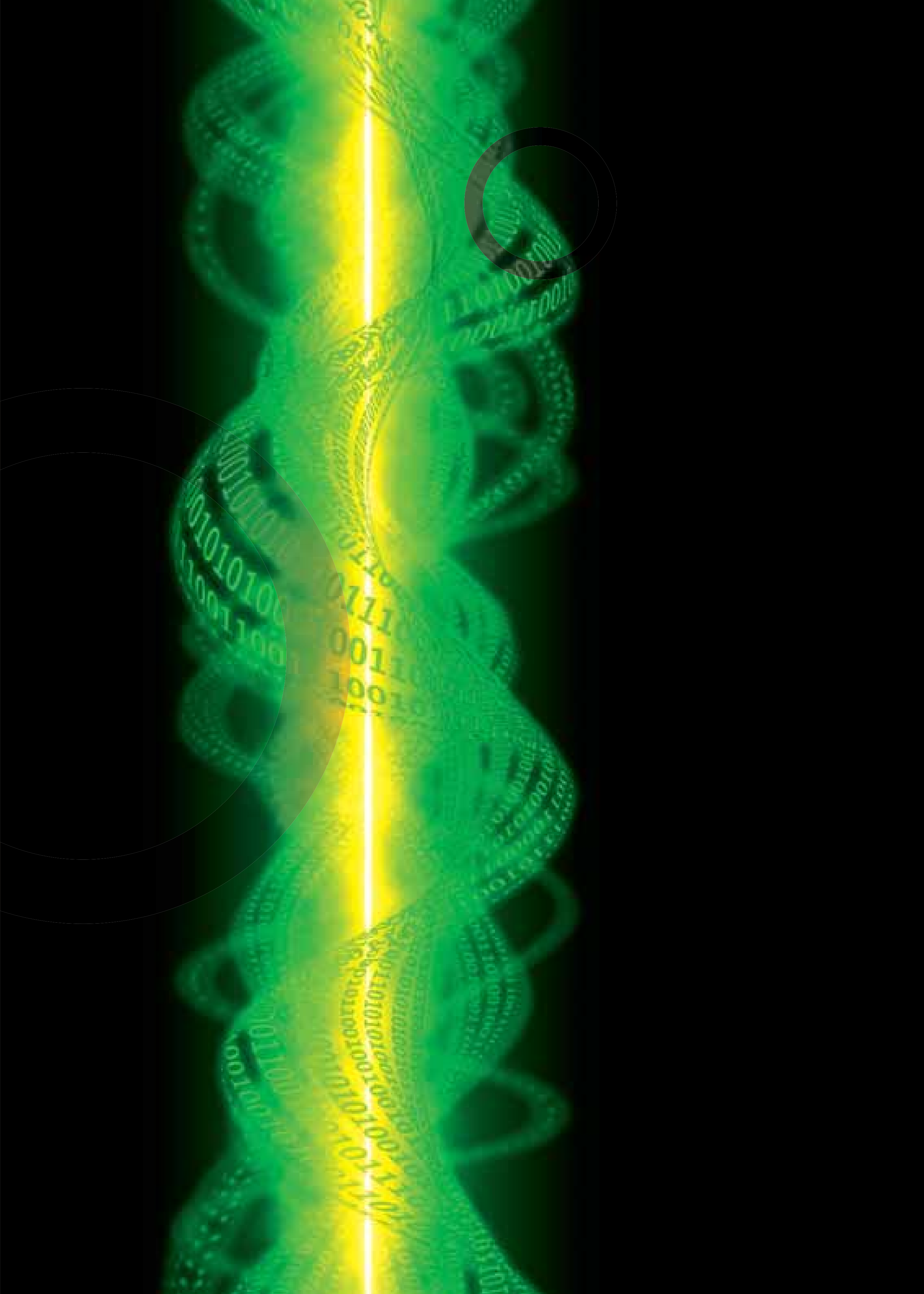
U radu je predstavljen model transformatora primjenjiv u niskofrekvencijskim elektromagnetskim prijelaznim pojavama, frekvencija reda oko 1 kHz. Analiziran je primjer uklapanja neopterećenog energetskog transformatora. Prvo je pokazan pojednostavljeni analitički pristup, a zatim, zbog njegova ograničenja, u analizu je uveden numerički pristup rješavanja krutih diferencijalnih jednadžbi koje opisuju prijelaznu pojavu. U oba slučaja je realiziran algoritam za generiranje valnih oblika varijabli stanja. Rezultati oba algoritma su uspoređeni s rezultatima MATLAB/Simulink/Power System Blockset, namjenskog programa za analizu elektromagnetskih prijelaznih pojava u elektroenergetskom sustavu. Razvijeni algoritam se može uspješno koristiti u ostalim niskofrekvencijskim prijelaznim pojavama gdje je glavni predmet analize nelinearni karakter transformatora: ferorezonancija, ispad tereta, kvarovi kod transformatora itd.

In this article, a transformer model is presented that is applicable to low frequency electromagnetic transient phenomena of up to 1 kHz. An example of the energization of a no-load transformer is analyzed. A simplified analytical approach is presented first. Due to the limitations of this approach, a numerical approach is introduced for the solution of the stiff differential equations that describe the transient phenomena. In both cases, algorithms have been developed for generating the waveforms of the state variables. The results of both algorithms are compared to the results of the MATLAB/Simulink/Power System Blockset for the analysis of electromagnetic transient phenomena in electrical energy systems.  Developed algorithm with the introduced numerical approach can be used successfully in other low frequency transient phenomena where the main subject of analysis is the nonlinear character of the transformer: ferroresonance, load switch-off, transformer faults etc.

Ključne riječi: implicitno trapezno pravilo, krivulja magnetiziranja, krute diferencijalne jednadžbe, uklapanje transformatora

Key words: implicit trapezoidal rule, magnetization curve, stiff differential equations, transformer energization



# 1 UVOD

U niskofrekvencijske prijelazne pojave u transformatorima se obično ubrajaju uklapanje neopterećenih transformatora i ferorezonancija. U spomenutim prijelaznim pojavama parametar, koji dominantno utječe na rezultate prijelaznih pojava, je nelinearni induktivitet željezne jezgre transformatora. Kao posljedica nelinearnosti jezgre može doći do jakih strujnih udara prilikom uklapanja neopterećenih transformatora. Osnovne karakteristike struja uklopa transformatora su relativno velika amplituda, koja dostiže ekstremno i do 10 $I_{naz}$ kao i relativno velika duljina trajanja do postizanja stacionarnog stanja [1]. Ovakve struje često mogu uzrokovati nepotrebno djelovanje zaštitnih uređaja budući da mogu dostići vrijednosti struja kratkog spoja transformatora. S tim u vezi, danas su razvijene različite metode za razlikovanje struje uklapanja od struje kratkog spoja transformatora. Najčešće upotrebljavane tehnike razlikovanja su: harmonijska analiza struje (praćenje drugog harmonika struje) [2], energetske metode [3], metode magnetskih karakteristika transformatora [4], te suvremene tehnike koje se baziraju na upotrebi wavelet transformacije i neuronskih mreža [5], suvremenih korelacijskih algoritama [6], itd.

Posljedica struja uklapanja neopterećenih transformatora mogu biti privremeni, niskofrekvencijski, nesinusoidalni prenaponi [7], koji mogu značajno energetski preopteretiti metal-oksidne odvodnike prenapona koji su instalirani uz transformatore [8]. Zagrijavanje odvodnika bitno zavisi od promatrane konfiguracije mreže i od parametara sustava kao i odgovarajućih početnih uvjeta (trenutak uklopa transformatora, remanentni magnetizam transformatora itd.). Amplituda i duljina trajanja ovakvih privremenih napona, a samim time i zagrijavanje odvodnika prenapona, su znatno izraženiji u uvjetima slabih elektroenergetskih sustava.

Dodatno, uklapanje, odnosno isklapanje transformatora u električnim krugovima koje sadrže kapacitivnosti može dovesti do dugotrajnih ferorezonantnih prekostruja, odnosno prenapona. Tipični primjeri nastanka ferorezonancije nastupaju pri serijskoj kompenzaciji [9] ili pri isklapanju naponskih mjernih transformatora [10], te pri neregularnim sklopnim operacijama trofaznih prekidača (prijevremeni uklop/isklop jedne faze u mrežama sa izoliranom neutralnom točkom) [11].

S obzirom na iznesene praktične strane problema pri niskofrekvencijskim prijelaznim pojavama transformatora, potrebno je naročitu pozornost usmjeriti na pravilno modeliranje transformatora, odnosno simuliranje spomenutih pojava.

# 1 INTRODUCTION

Low frequency transient phenomena in transformers usually include the inrush currents of no-load transformers and ferroresonance. In these transients, the parameter with the dominant impact on the results is the nonlinear inductance of the iron core. As a consequence of the nonlinearity of the core, high inrush currents can occur when energizing no-load transformers. The basic characteristics of transformer inrush currents are relatively high amplitude, which in extreme cases can reach up to 10 $I_{rated}$ as well as the relatively long period of time until a steady state is reached [1]. Such currents frequently can cause unnecessary tripping to occur because they can reach the short-circuit current values of the transformers. In connection with this, various methods have been developed today for differentiating between transformer inrush current and short-circuit current. The most frequently used differentiation techniques are as follows: harmonic analysis of the current (second harmonic component) [2], power differential methods [3], methods based on transformer magnetizing characteristics [4], modern techniques that are based on the use of wavelet transform and neural networks [5], modern correlation algorithms [6] etc.

Consequences of no-load transformer inrush currents can be temporary, low frequency and nonsinusoidal overvoltages [7], which can significantly overload the metal oxide surge arresters that are installed next to the transformers [8]. The thermal stress on surge arresters depends significantly on the network configuration and the system parameters as well as the initial conditions (the instant of energization, remnant magnetism etc.). The amplitude and duration of such transient voltages, together with the thermal stress on surge arresters, are significantly more marked under the conditions of weak powersystems.

Additionally, energizing and de-energizing transformers in electrical networks with capacitance can lead to long term overcurrents or overvoltages due to ferroresonance. Typical examples of ferroresonance occur in series compensation [9], when switching off voltage measuring transformers [10] and due to the abnormal switching operations of three-phase switches (the premature energizing/de-energizing of a transformer phase in networks with an isolated neutral point) [11].

Taking into account the above-described practical aspect of the problem with the low frequency transient phenomena of transformers, particular attention should be devoted to the correct modeling of transformers, i.e. the simulation of these phenomena.

Kao što je već spomenuto, osnovna poteškoća u modeliranju energetskih transformatora je nelinearni karakter induktiviteta željezne jezgre transformatora. Ostali parametri transformatora: otpor i rasipni induktiviteti primarnog i sekundarnog namota kao i otpor koji reprezentira gubitke u željezu uzimaju se konstantnim [12]. Osnovna krivulja magnetiziranja transformatora dana je na slici 1a. Ova krivulja se može kvalitativno aproksimirati s dva pravca, slika 1b, koji predstavljaju tangente u nezasićenom i zasićenom području. Krivulja magnetiziranja energetskih transformatora ima jako oštar prijelaz iz nezasićenog u zasićeno područje. Ovo je posljedica konstruktivne izvedbe visokonaponskih energetskih transformatora. Naime, s porastom naponske razine, odnosno nazivne snage transformatora struja praznog hoda se smanjuje i iznosi [13] oko 5 % do10 % nazivne struje transformatora za transformatore snaga reda 100 kVA i opada sve do vrijednosti oko 0,47 % do 0,59 % nazivne struje transformatora za transformatore snage reda 500 MVA.

Pregled standardnih vrijednosti struje magnetiziranja za energetske transformatore različitih nazivnih snaga dan je tablicom 1. Struja prijelaza u zasićeno područje $i_z$ jednaka je nazivnoj struji pomnoženoj s faktorom ulaska u zasićenje $k$: $i_z = k \cdot i_{0\mathrm{naz}}$, gdje je za energetske transformatore obično $1{,}05 \leq k \leq 1{,}3$. Dakle, koljeno krivulje magnetiziranja za energetske transformatore velikih snaga je razmješteno u veoma uskom području nazivne struje transformatora (reda 0,5 % do 1 % $i_{\mathrm{naz}}$). Površina, koja je omeđena realnom krivuljom magnetiziranja i njenom aproksimacijom preko dva pravca, ovdje je reda svega oko 0,001 % ako uzmemo da je 100 % površina ispod cijele krivulje magnetiziranja u p.u. sistemu. Logična je posljedica ovako malih nazivnih struja praznog hoda da predstavljanje krivulje magnetiziranja preko svega dva pravca čini gotovo zanemarive pogreške u usporedbi s realnim predstavljanjem krivulje [14].

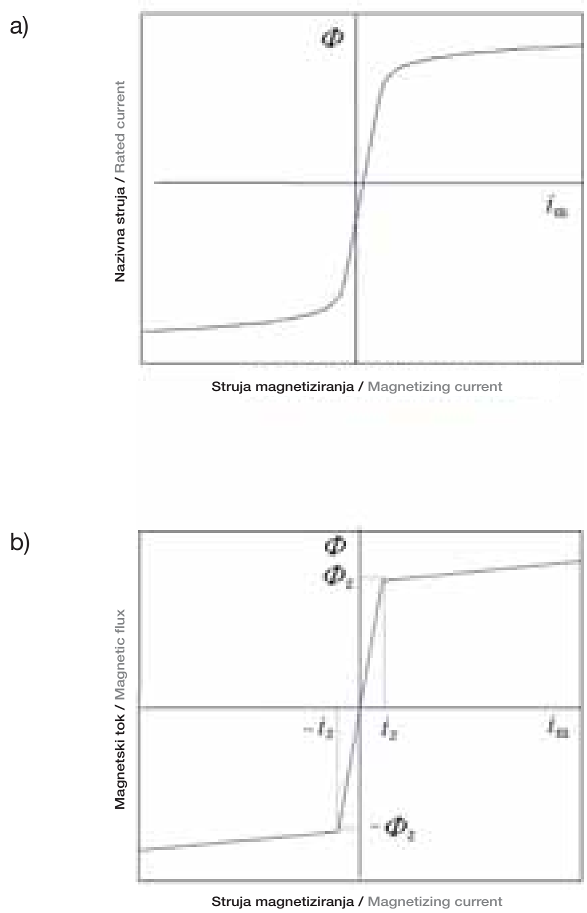
As previously mentioned, the basic difficulty in modeling power transformers is the nonlinear character of the inductance of the iron transformer core. The other transformer parameters, the resistance and leakage inductance of the primary and secondary windings as well as the resistance that represents losses in iron are assumed to be constant [12]. The basic transformer magnetizing curve is presented in Figure 1a. This curve can be qualitatively approximated with two straight lines, Figure 1b, that represent tangents in the unsaturated and saturated regions. The power transformer magnetizing curve has a very sharp transition from the unsaturated to the saturated regions. This is a consequence of the design of high voltage power transformers. With an increase in the voltage level or rated power of the transformer, no-load current is decreased and amounts to approximately 5 % to 10 % of the transformer rated current [13] for transformers with power ratings of 100 kVA and decreases to a value of approximately 0,47 % to 0,59 % of transformer rated current for transformers with power ratings of 500 MVA.

A review of the standard values of power transformer magnetizing currents for various rated powers is presented in Table 1. The transition current to the saturated region $i_z$ is equal to the rated current multiplied by the saturation factor $k$: $i_z = k \cdot i_{0\mathrm{rated}}$, where usually for power transformers $1{,}05 \leq k \leq 1{,}3$. Thus, the bend in the magnetizing curve for a high power transformer is in a very narrow region of the transformer rated current (an order of 0,5 % to 1 % $i_{\mathrm{rated}}$). The surface, which is bounded by the real magnetizing curve and its approximation by two straight lines is of an order here of only approximately 0,001 % if it is taken into account that 100 % of the surface below the magnetizing curve is in a p.u. system. A logical consequence of such low rated no-load currents is that it is possible to approximate the magnetizing curve using two straight lines with nearly negligible error in comparison to the real curve [14].

Tablica 1 –Tipične vrijednosti struje praznog hoda kao postotak nazivne struje za energetske transformatore
Table 1 –Typical values of no-load current as a percentage of rated current for power transformers

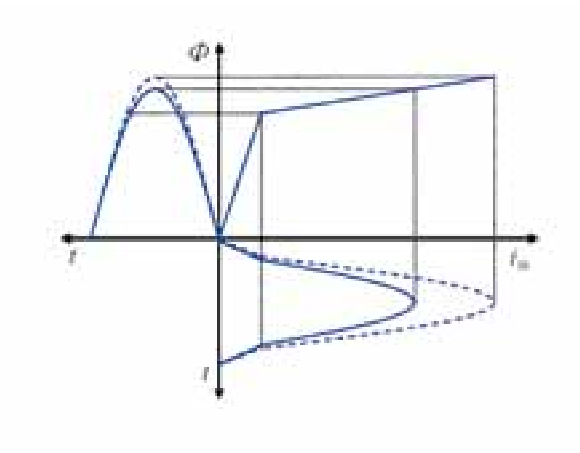
| | | | | | | |
|---|---|---|---|---|---|---|
| $S_{\mathrm{TR}}$ (MVA) | 0,1 | 1,0 | 10 | 20 | 40 | 60 |
| $i_0$ (% $i_{\mathrm{naz/rated}}$) | 5,0 – 8,0 | 1,75 – 2,32 | 0,35 – 1,1 | 0,8 – 1,2 | 0,65 – 0,94 | 0,58 – 0,84 |
| $S_{\mathrm{TR}}$ (MVA) | 80 | 100 | 150 | 200 | 300 | 500 |
| $i_0$ (% $i_{\mathrm{naz/rated}}$) | 0,54 – 0,77 | 0,51 – 0,73 | 0,47 – 0,67 | 0,51 – 0,64 | 0,49 – 0,61 | 0,47 – 0,59 |

Slika 1
Krivulja magnetiziranja transformatora a) i njena aproksimacija preko dva pravca b)
Figure 1
Magnetizing curve of transformer a) and its approximation via two straight lines b)

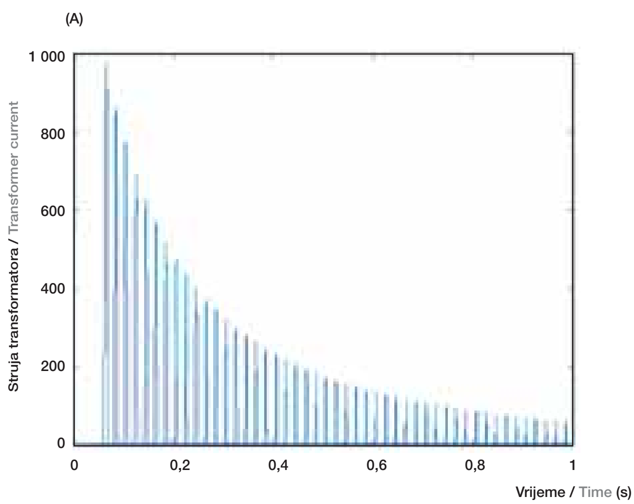



Posljedica nelinearnog karaktera željezne jezgre transformatora je nesinusoidalna struja magnetiziranja transformatora pri sinusoidalnom naponu napajanja, tj. sinusoidalnom magnetskom toku, što je jasno ilustrirano na slici 2. Na istoj slici su prikazana dva oblika struje magnetiziranja za dvije različite tjemene vrijednosti magnetskog toka. Tijekom prijelazne pojave uklapanja transformatora kada magnetski tok može poprimi vrijednosti i veće od svoje dvostruke nazivne vrijednosti [15], dolazi do jakih strujnih udara transformatora, što je pokazano na slici 3.

A consequence of the nonlinear character of the iron transformer core is the nonsinusoidal transformer magnetizing current at the sinusoidal supply voltage, i.e. sinusoidal magnetic flux, which is clearly illustrated in Figure 2. In the same figure, two forms of magnetizing current are presented for two different peak values of the magnetic flux. During the transient phenomena of transformer energization, when the magnetic flux can acquire values greater than twice its rated value [15], high inrush current occurs, as presented in Figure 3.




**Slika 2**
Nesinusoidalna struja magnetiziranja transformatora
**Figure 2**
Nonsinusoidal transformer magnetizing current




**Slika 3**
Tipičan valni oblik struje uklapanja transformatora
**Figure 3**
Typical waveform of transformer inrush current

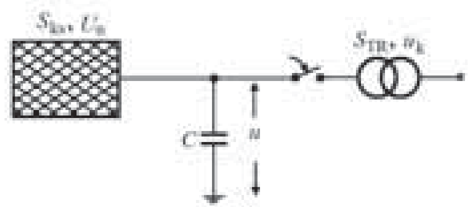
## 2 MATEMATIČKI MODEL PRI UKLAPANJU NEOPTEREĆENOG ENERGETSKOG TRANSFORMATORA

U ovom poglavlju će se analizirati matematički model pri uklapanju neopterećenog energetskog transformatora, slika 4a i b. Između transformatora i točke priključka na mrežu postoji kapacitet $C$, kojim se ekvivalentira prilaz kabelskim ili nadzemnim vodom, kapacitet kondenzatorskih baterija i sl.

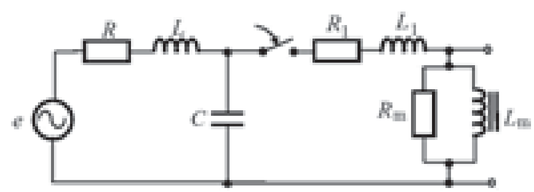
## 2 MATHEMATICAL MODEL OF THE ENERGIZATION OF A NO-LOAD POWER TRANSFORMER

This chapter presents an analysis of a mathematical model of the energization of a no-load power transformer, Figures 4a and b. Between the transformer and the connection point to the network, there is a capacity $C$, which is equivalent to the capacity of a cable or overhead approach line, the capacitance of the capacitors etc.

**Slika 4** Uklapanje neopterećenog energetskog transformatora
**Figure 4** The energization of a no-load power transformer




a) Shema uklapanja transformatora na mrežu / Simplified electrical circuit of transformer energization




b) Odgovarajuća zamjenska shema slike a) / Equivalent electrical circuit of Figure a)

Parametri mreže se dobivaju iz podataka o snazi tropolnog kratkog spoja u točki priključka:

The network parameters are obtained from data on the three-phase short-circuit power at the point of connection:

$$L = \frac{U_n^2}{S_{ks} \cdot \omega} \quad . \tag{1}$$

Pretpostavlja se da je odnos $X / R$ za danu mrežu poznat, na osnovi kojega se određuje otpor $R$.

Na osnovi poznate nazivne snage transformatora $S_{TR}$, te napona kratkog spoja moguće je odrediti rasipni induktivitet tansformatora:

It is assumed that the ratio of $X / R$ for the given network is known, on the basis of which we determine resistance $R$.

On the basis of the known transformer rated power $S_{TR}$ and the short-circuit voltage, it is possible to determine the leakage inductance of the transformer:

$$L_1 = \frac{U_n^2}{S_{TR} \cdot \omega} \cdot u_k \, . \tag{2}$$

Ostali podaci, djelatni otpor primarnog namota transformatora $R_1$, djelatni otpor izazvan gubicima u željezu $R_m$, te nelinearni induktivitet željezne

Other data, the effective resistance of the primary transformer winding $R_1$, the effective resistance due to iron core losses $R_m$, and the nonlinear inductance

jezgre transformatora $L_m$, inače definirana krivuljom magnetiziranja $\Phi$-$i_m$ ($\Phi$ je glavni ulančeni magnetski tok, $i_m$ je struja magnetiziranja transformatora), lako se mogu odrediti mjerenjem ili su već dani od strane proizvođača. Ovaj nelinearni induktivitet aproksimiran je s dva pravca u $\Phi$-$i_m$ koordinatnom sustavu, slika 2, što je za energetske transformatore u praksi uglavnom prihvatljivo. Točka ($i_z$, $\Phi_z$) predstavlja kritičnu točku pri prelasku iz nezasićenog u zasićeno područje željezne jezgre. Koeficijenti pravaca ustvari predstavljaju induktivitete u nezasićenom ($L_{m1}$, const$_1$) i zasićenom području ($L_{m2}$, const$_2$). Na ovaj način dobivamo funkcionalnu ovisnost struje magnetiziranja o magnetskom toku kao (funkcijom *sign* osiguravamo pozicioniranje u odgovarajućem kvadrantu):

of the transformer iron core $L_m$, otherwise defined by the magnetizing curve $\Phi$-$i_m$ ($\Phi$ is the main linkage magnetic flux, $i_m$ is the transformer magnetizing current), can easily be determined through measurement or are already provided by the manufacturer. This nonlinear inductance is approximated with two straight lines in the $\Phi$-$i_m$ coordinate system, Figure 2, which is generally acceptable in practice for power transformers. Point ($i_z$, $\Phi_z$) represents the critical point at the transition from the unsaturated region to the saturated region of the iron core. The straight lines coefficients actually represent inductances in the unsaturated region $L_{m1}$, const$_1$ and saturated region $L_{m2}$, const$_2$. In this manner, we obtain the functional dependence of the magnetizing current on the magnetic flux (we define the position in the corresponding quadrant with the *sign* function) as follows:

$$i_m = \frac{1}{L_{m1}}\Phi, \quad |\Phi| \le \Phi_z, \tag{3}$$

$$i_m = \frac{1}{L_{m2}}\Phi + \mathrm{sign}(\Phi)\left(\frac{1}{L_{m1}} - \frac{1}{L_{m2}}\right)\Phi_z, \quad |\Phi| > \Phi_z. \tag{4}$$

## 3 ANALITIČKI PRISTUP

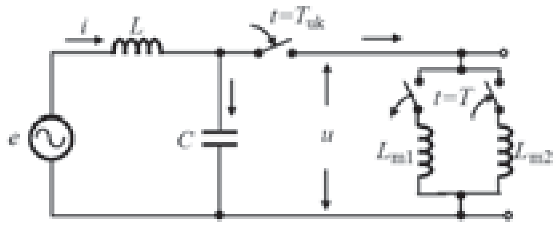
Radi jednostavnosti zanemarit će se sve aktivne elemente sa slike 4b. Dakle, pri prijelaznoj pojavi uklapanja transformatora ako trenutačna vrijednost magnetskog toka, po apsolutnoj vrijednosti premaši kritičnu vrijednost $\Phi_z$, induktivnost transformatora se mijenja sa $L_{m1}$ na $L_{m2}$. To ustvari znači da se trenutak kada magnetski tok dostigne vrijednost $\Phi_z$ može uzeti kao vrijeme $t=T>T_{uk}$ isklapanja induktiviteta $L_{m1}$ odnosno uklapanja induktiviteta $L_{m2}$. Ekvivalentna shema bi u tom slučaju izgledala kao na slici 5. Slično, pri smanjenju magnetskog toka ispod vrijednosti $\Phi_z$ isključuje se induktivitet $L_{m2}$ i uključuje induktivitet $L_{m1}$.

## 3 ANALYTICAL APPROACH

For the purpose of simplicity we shall ignore all the active elements from Figure 4b. In the transient phenomena during transformer energization, if the instantaneous value of the magnetic flux in terms of absolute value exceeds the critical value of $\Phi_z$, the transformer inductance changes from $L_{m1}$ to $L_{m2}$. This actually means that the moment when the magnetic flux reaches the value of $\Phi_z$ can be taken as the time $t=T>T_{uk}$ of switching off the inductance $L_{m1}$, respectively the time of switching on the inductance $L_{m2}$. In this case, an equivalent diagram would look like the one presented in Figure 5. Similarly, when the magnetic flux is decreased below the value of $\Phi_z$, inductance $L_{m2}$ is switched off and inductance $L_{m1}$ is switched on.

**Slika 5**
Uklapanje transformatora – pojednostavljeni model

**Figure 5**
Transformer energization – simplified model



Dakle, promjena trenutačne vrijednosti magnetskog toka pri prelaznoj pojavi uvjetuje prelaske s jednog na drugi pravac što u diferencijalnim jednadžbama koje opisuju ponašanje električnih krugova ustvari znači promjenu koeficijenata. Proces počinje s induktivitetom $L_{m1}$. Uz oznake kao na slici 5 dobiju se diferencijalne jednadžbe koje opisuju ponašanje električnog kruga u proizvoljnom trenutku $t \geqslant T_{uk}$, gdje je $t=T_{uk}$ trenutak uklapanja prekidača :

Therefore, in transient phenomena transition from one straight line to another is conditional upon change in the instantaneous value of the magnetic flux, which in differential equations that describe the behavior of electric circuits actually signifies coefficient changes. The process begins with the inductance $L_{m1}$. Using the same symbols as in Figure 5, differential equations are obtained that describe the behavior of the electric circuit at the arbitrary moment $t \geqslant T_{uk}$ , where $t=T_{uk}$ is the moment that the switch is turned on:

$$E_m \cos \omega t = \frac{d^2 \Phi}{dt^2} + \frac{1}{C}\left(\frac{1}{L_{m1}} + \frac{1}{L}\right)\frac{d\Phi}{dt}, \ |\Phi| \leq \Phi_z , \quad (5)$$

$$E_m \cos \omega t = \frac{d^2 \Phi}{dt^2} + \frac{1}{C}\left(\frac{1}{L_{m2}} + \frac{1}{L}\right)\frac{d\Phi}{dt}, \ |\Phi| > \Phi_z . \quad (6)$$

Rješava se prvo diferencijalna jednadžba (5). Uz izraz za prirodnu kružnu frekvenciju kruga:

Differential equation (5) is solved first. When the natural circular frequency of the circuit is as follows:

$$\omega_{01} = \sqrt{\frac{1}{C}\left(\frac{1}{L_{m1}} + \frac{1}{L}\right)}, \quad (7)$$

dobiva se opće rješenje diferencijalne jednadžbe (5):

the general solution to equation (5) is obtained:

$$\Phi(t) = a + b\cos \omega_{01} t + c \sin \omega_{01} t + B \sin \omega t . \quad (8)$$

Konstante $a$, $b$ i $c$ određuju se iz početnih uvjeta:

Constants $a$, $b$ and $c$ are determined from the initial conditions:

$$\Phi(T_{uk}) = \Phi_0 , \tag{9}$$

$$u(T_{uk}) = \left.\frac{d\Phi}{dt}\right|_{t=T_{uk}} = U_0 , \tag{10}$$

$$i_C(T_{uk}) = C\left.\frac{du}{dt}\right|_{t=T_{uk}} = C\left.\frac{d^2\Phi}{dt^2}\right|_{t=T_{uk}} = I_{C0} . \tag{11}$$

Napon $U_0$ i struja $I_{C0}$ se određuju iz stanja prije uklapanja prekidača:

Voltage $U_0$ and current $I_{C0}$ are determined from the state prior to turning on the switch:

$$U_0 = \frac{E_m}{1-\omega^2 LC}\cos\omega T_{uk} , \tag{12}$$

$$I_{C0} = -\frac{\omega C E_m}{1-\omega^2 LC}\sin\omega T_{uk} . \tag{13}$$

Koeficijenti $a$, $b$ i $c$ se dobivaju iz matrične jednadžbe koja se formira na osnovi jednadžbi (9) do (13):

Coefficients $a$, $b$ and $c$ are obtained from the matrix equation formed on the basis of equations (9) to (13):

$$\boldsymbol{M} = \boldsymbol{K}^{-1}\cdot \boldsymbol{N}, \tag{14}$$

gdje su matrice ***M*, *K*** i ***N*** redom:

where matrices ***M***, ***K*** and ***N*** are as follows:

$$\boldsymbol{M} = \begin{bmatrix} a \\ b \\ c \end{bmatrix} , \tag{14a}$$

$$\boldsymbol{K} = \begin{bmatrix} 1 & \cos\omega_{01} T_{uk} & \sin\omega_{01} T_{uk} \\ 0 & -\omega_{01}\sin\omega_{01} T_{uk} & \omega_{01}\cos\omega_{01} T_{uk} \\ 0 & -\omega_{01}^2\cos\omega_{01} T_{uk} & -\omega_{01}^2\sin\omega_{01} T_{uk} \end{bmatrix} , \tag{14b}$$

$$\boldsymbol{N} = \begin{bmatrix} \Phi_0 - B\sin\omega T_{uk} \\ U_0 - B\omega\cos\omega T_{uk} \\ I_0 / C + B\omega^2\sin\omega T_{uk} \end{bmatrix} . \tag{14c}$$

Kada se odrede konstante $a$, $b$ i $c$ tada se za vremenski oblik magnetskog toka $\Phi(t)$, napona $u(t)$ na transformatoru i struje kondenzatora $i_C(t)$ dobiva:

When constants $a$, $b$ and $c$ are determined, the magnetic flux $\Phi(t)$, transformer voltage $u(t)$ and condenser current $i_C(t)$ waveforms as a function of time are then as follows:

$$\Phi(t) = a + b\cos\omega_{01}t + c\sin\omega_{01}t + B\sin\omega t\ , \tag{15}$$

$$u(t) = -b\omega_{01}\sin\omega_{01}t + c\omega_{01}\cos\omega_{01}t + B\omega\cos\omega t\ , \tag{16}$$

$$i_C(t) = C\left(-b\omega_{01}^2\cos\omega_{01}t - c\omega_{01}^2\sin\omega_{01}t - B\omega^2\sin\omega t\right). \tag{17}$$

U jednadžbi (8) konstanta $a$ predstavlja istosmjernu komponentu magnetskog toka, $b$, $c$ i $\omega_{01}$ konstante kojima je definiran vlastiti odziv, a $B$ i $\omega$ konstante kojima je definiran prinudni odziv u rješenju za magnetski tok. Posljednje tri jednadžbe vrijede sve dok je zadovoljeno $|\Phi| \leq \Phi_z$. U protivnom, kada bude $|\Phi| > \Phi_z$ tada ponašanje električnog kruga opisuje diferencijalna jednadžba (6) opisuje stanje ravnoteže s parametrom $L_{m2}$ umjesto $L_{m1}$. Početni uvjeti za novu diferencijalnu jednadžbu (6) su posljednje trenutačne vrijednosti rješenja prvobitne jednadžbe (5). Rješenja diferencijalne jednadžbe (6) se dobivaju istim postupkom kao rješenja jednadžbe (5). Analogno se razmišlja pri ponovnom smanjenju magnetskog toka ispod vrijednosti $\Phi_z$ sa odgovarajućim početnim uvjetima koji su određeni posljednjim trenutačnim vrijednostima stare diferencijalne jednadžbe.

Struja magnetiziranja transformatora $i_m$ određuje se na osnovi relacija (3) i (4).

Generalno se može organizirati algoritam koji bi prateći vrijednost trenutačnog magnetskog toka rješavao diferencijalne jednadžbe (5) i (6) s odgovarajućim početnim uvjetima. Uvodeći težinske koeficijente $k_1$ i $k_2$ koji bi uzimali vrijednosti 0 ili 1 moguće je načiniti petlju koja bi stalno računala vrijednost magnetskog toka u zasićenom ili nezasićenom području vodeći računa o odgovarajućim početnim uvjetima.

Remanentni magnetizam transformatora $\Phi_{rem}$ moguće je uvažiti ako se u proračun krene s tom vrijednošću, $\Phi(T_{uk}) = \Phi_{rem}$. Histerezna petlja je zanemarena, što je u praktičkim primjerima za energetske transformatore sasvim prihvatljivo [16].

In equation (8), constant $a$ represents the DC component of the magnetic flux, $b$, $c$ and $\omega_{01}$ are the constants by which the self response is defined, and $B$ and $\omega$ are the constants by which the forced response is defined in the solution for the magnetic flux. The last three equations are valid until the condition of $|\Phi| \leq \Phi_z$ is met. Otherwise, when $|\Phi| > \Phi_z$, differential equation (6) describes the behavior of the electric circuit with the parameter $L_{m2}$ instead of $L_{m1}$. The initial conditions for a new differential equation (6) are the last instantaneous values from the solution of equation (5). The solution to differential equation (6) is obtained according to the same procedure as the solution to equation (5). An analogous procedure is used when the magnetic flux is again reduced below the value of $\Phi_z$ with the corresponding initial conditions that are determined using the instantaneous values of the previous differential equation.

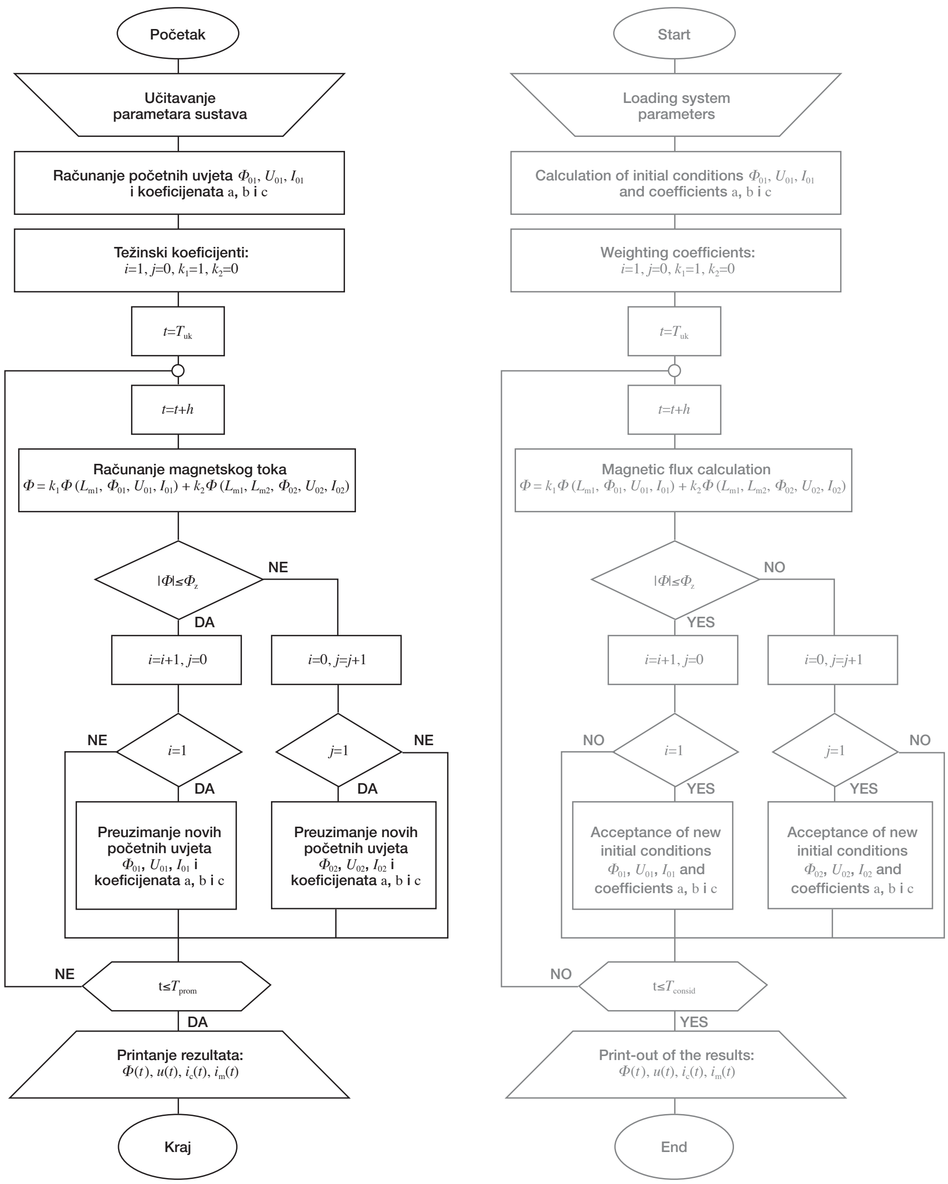
The transformer magnetizing current $i_m$ is determined on the basis of equations (3) and (4).

It is generally possible to develop an algorithm that would solve differential equations (5) and (6) by following the value of the instantaneous magnetic flux with the corresponding initial conditions. By introducing weighting coefficients $k_1$ and $k_2$ that would assume the value of 0 or 1, it is possible to make a loop that that would constantly calculate the value of the magnetic flux in the saturated and unsaturated regions, taking the corresponding initial conditions into account.

Transformer remnant magnetism, $\Phi_{rem}$ can be taken into account if this value is entered into the calculation $\Phi(T_{uk}) = \Phi_{rem}$. The hysteresis loop is ignored, which is completely acceptable in practical applications for power transformers [16].

Pojednostavljeni algoritam računanja varijabli stanja (magnetskog toka, napona i struje) dan je na slici 6. Otežavajuća činjenica pri realizaciji programa je da se početni uvjeti pri svakom prijelazu iz jednog u drugo područje stalno moraju preračunavati.

A simplified algorithm for the calculation of state variables (magnetic flux, voltage and current) is presented in Figure 6. A complicating factor in the implementation of the program is that the initial conditions at every transition from one region to another must constantly be recalculated.




**Slika 6**
Razvijeni algoritam, pojednostavljeni model
**Figure 6**
Developed algorithm, simplified model

## 4 NUMERIČKI PRISTUP

Sada će se analizirati slučaj uklapanja transformatora sa svim elementima prema slici 7. Dok se transformator još uvijek nalazi u nezasićenom području, gdje će se radi jednostavnosti induktivitet željezne jezgre označiti s $L_m$, vrijede jednadžbe:

## 4 NUMERICAL APPROACH

A case will now be analyzed of the energization of a transformer with all the elements according to Figure 7. While the transformer is still in the unsaturated region, where for purposes of simplicity the inductance of the iron core will be designated by $L_m$, the following equations apply:

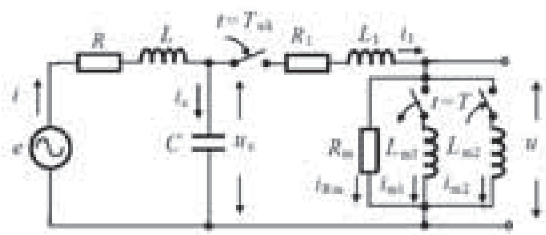
$$e = E_m \cos \omega t = R \cdot i + L \frac{\mathrm{d}i}{\mathrm{d}t} + u_C , \tag{18}$$

$$i = i_C + i_1 = C \frac{\mathrm{d}u_C}{\mathrm{d}t} + i_1 , \tag{19}$$

$$i_1 = i_{Rm} + i_m = \frac{1}{R_m} u + \frac{1}{L_m} \Phi = \frac{1}{R_m} \frac{\mathrm{d}\Phi}{\mathrm{d}t} + \frac{1}{L_m} \Phi , \tag{20}$$

$$u_C = R_1 \cdot i_1 + L_1 \frac{\mathrm{d}i_1}{\mathrm{d}t} + u = R_1 \cdot i_1 + L_1 \frac{\mathrm{d}i_1}{\mathrm{d}t} + \frac{d\Phi}{\mathrm{d}t} . \tag{21}$$

**Slika 7**
Uklapanje transformatora – potpuni model
**Figure 7**
Transformer energization – complete model



Transformacijom posljednje četiri jednadžbe dolazimo do diferencijalne jednadžbe četvrtog reda oblika:

Through the transformation of the last four equations, we arrive at fourth-order differential equations:

$$e = a_4 \frac{\mathrm{d}^4 \Phi}{\mathrm{d}t^4} + a_3 \frac{\mathrm{d}^3 \Phi}{\mathrm{d}t^3} + a_2 \frac{\mathrm{d}^2 \Phi}{\mathrm{d}t^2} + a_1 \frac{\mathrm{d}\Phi}{\mathrm{d}t} + a_0 \Phi , \tag{22}$$

gdje su konstante $a_i$, $i = 0, 1, 2, 3, 4$ dane sa:

where the constants $a_i$, $i = 0, 1, 2, 3, 4$ are as follows:

$$a_0 = \frac{R}{L_m} + \frac{R_1}{L_m}, \tag{22a}$$

$$a_1 = R\left(\frac{C \cdot R_1}{L_m} + \frac{1}{R_m}\right) + \frac{L}{L_m} + \frac{R_1}{R_m} + \frac{L_1}{L_m} + 1, \tag{22b}$$

$$a_2 = R \cdot C\left(\frac{R_1}{R_m} + \frac{L_1}{L_m} + 1\right) + L\left(\frac{C \cdot R_1}{L_m} + \frac{1}{R_m}\right) + \frac{L_1}{R_m}, \tag{22c}$$

$$a_3 = \frac{R \cdot C \cdot L_1}{R_m} + L \cdot C\left(\frac{R_1}{R_m} + \frac{L_1}{L_m} + 1\right), \tag{22d}$$

$$a_4 = \frac{L \cdot C \cdot L_1}{R_m}. \tag{22e}$$

Uz realne podatke [8]:

- $E_m$ = 172 kV,
- $R$ = 8,82 Ω,
- $L$ = 0,281 H,
- $C$ = 4,218 μF,
- $R_1$ = 0,529 Ω,
- $L_1$ = 0,126 H,
- $\Phi_z$ = 657,88 W,
- $L_{m1}$ = 185,24 H,
- $L_{m2}$ = 0,253 H,
- $R_m$ = 0,576 $\cdot 10^6$ Ω,

primjenjujući Bairstow numeričku metodu, za korjene karakteristične jednadžbe bi dobili rješenja:

with real data [8]:

- $E_m$ = 172 kV,
- $R$ = 8,82 Ω,
- $L$ = 0,281 H,
- $C$ = 4,218 μF,
- $R_1$ = 0,529 Ω,
- $L_1$ = 0,126 H,
- $\Phi_z$ = 657,88 W,
- $L_{m1}$ = 185,24 H,
- $L_{m2}$ = 0,253 H,
- $R_m$ = 0,576 $\cdot 10^6$ Ω,

and by applying the Bairstow numerical method, the roots of the characteristic equation are obtained as follows:

$$p_1 = -4{,}575 \cdot 10^6 = -\alpha, \tag{23}$$

$$p_2 = -0{,}0504 = -\beta, \tag{24}$$

$$p_{3,4} = -15{,}876 \pm \mathrm{j}919{,}096 = -\gamma \pm \mathrm{j}\omega_0. \tag{25}$$

Tada je opće rješenje jednadžbe (22):

Then the general solution of the equation (22) is:

$$\Phi(t) = a \cdot e^{-\alpha t} + b \cdot e^{-\beta t} + e^{-\gamma t}\left(c \cdot \cos\omega_0 t + d \cdot \sin\omega_0 t\right) + B \cdot \sin(\omega t + \Psi). \tag{26}$$

Očita je jaka rasutost korijena $p_1$ i $p_2$. Kada bi po analogiji na razmatranje kao u poglavlju 3 formirali matrice $\boldsymbol{M}$, $\boldsymbol{K}$ i $\boldsymbol{N}$, lako bismo zaključili da matrica $\boldsymbol{K}$ predstavlja singularnu matricu, jer u prvom stupcu sadrži umnoške broja $e^{p_1 T_{uk}}$. Svi ti brojevi su za računalo praktički jednaki nuli zbog goleme vrijednosti $p_1$. Dakle, klasičan analitički pristup u općem se slučaju ne bi mogao provesti zbog singularnosti matrice $\boldsymbol{K}$. U daljem dijelu razmatrat će se numerički pristup rješavanja ovog problema. Međutim, i pri numeričkom pristupu veoma je važno obratiti pozornost na izbor odgovarajućeg numeričkog postupka zbog istaknute činjenice da su korijeni karakteristične jednadžbe jako rasuti u lijevom dijelu kompleksne ravnine. Jaka disperzija korijena karakteristične jednadžbe definira zasebnu klasu diferencijalnih jednadžbi poznatih pod imenom krute diferencijalne jednadžbe (*stiff differential equations*). Naime, diskutabilna je apsolutna stabilnost numeričkih postupaka primijenjenih na ovu vrstu jednadžbi [17]. Nijedan od klasičnih numeričkih postupaka u eksplicitnoj formi, bio jednokoračni ili višekoračni tipa Eulera, Runge-Kuta, Adams-Moulton itd. pri standardnim koracima integracije, ne osigurava apsolutnu stabilnost postupka, što dovodi do divergiranja rješenja u numeričkom smislu (pogreška $\delta_k$ u $k$-toj iteraciji izaziva u $k$+1-oj iteraciji pogrešku $\delta_{k+1} > \delta_k$). Apsolutnu stabilnost osiguravaju jedino implicitni numerički postupci [17] i [18], mada i pri njihovoj upotrebi treba biti jako oprezan. U konkretnom primjeru upotrijebljeno je apsolutno stabilno implicitno trapezno pravilo.

High dispersion of the roots $p_1$ and $p_2$ is evident. If matrices $\boldsymbol{M}$, $\boldsymbol{K}$ and $\boldsymbol{N}$ are formed, analogically to the discussion in Chapter 3, it could be easily concluded that matrix $\boldsymbol{K}$ represents a singular matrix because it contains multiples of the number $e\, p_1 T_{uk}$ in the first column. All these numbers are practically equal to zero for a computer due to the enormous value of $p_1$. Therefore, the classical analytical approach in a general case could not be implemented due to the singularity of matrix $\boldsymbol{K}$. The numerical approach to the solution of this problem will be discussed subsequently. However, with the numerical approach it is very important to pay attention to the selection of the suitable numerical approach procedure due to the significant fact that the roots of the characteristic equation are highly dispersed in the left part of the complex plain. The high root dispersion of the characteristic equation defines a separate class of differential equations known as stiff differential equations. The absolute stability of the numerical approaches applied in this type of equation is disputable [17]. None of the classical numerical approaches in explicit form, whether of the single-step or multistep Euler, Runge-Kutta, Adams-Moulton type etc. using standard integration steps, assures the absolute stability of the procedure, which leads to divergence of the solutions in the numerical sense (error $\delta_k$ in the $k$-*th* iteration causes error $\delta_{k+1} > \delta_k$ in the $k$+1 iteration). Only implicit numerical procedures guarantee absolute stability [17] and [18], although it is necessary to use them very cautiously. In a concrete example, the absolutely stable implicit trapezoidal rule is applied.

Jednadžbe (18) do (22) će se napisati u prostoru stanja uzimajući da je vektor varijabli stanja:

Equations (18) to (22) can be written in the state space form where the state variable vector is:

$$\boldsymbol{x} = \begin{bmatrix} i & u_C & i_1 & \Phi \end{bmatrix}^T. \tag{27}$$

Za nezasićeno područje gdje inače vrijedi:

For the unsaturated region where the following otherwise applies:

$$i_m = \frac{1}{L_{m1}}\Phi \quad \text{za / for} \quad |\Phi| \le \Phi_z, \tag{28}$$

dobiva se jednadžba u prostoru stanja: the following state space equation is obtained:

$$\dot{x} = A_1 x + b_1, \tag{29}$$

gdje su: Where:

$$A_1 = \begin{bmatrix} -\frac{R}{L} & -\frac{1}{L} & 0 & 0 \\ \frac{1}{C} & 0 & -\frac{1}{C} & 0 \\ 0 & \frac{1}{L_1} & -\left(\frac{R_1}{L_1} + \frac{R_m}{L_1}\right) & \frac{R_m}{L_1 L_{m1}} \\ 0 & 0 & R_m & -\frac{R_m}{L_{m1}} \end{bmatrix}, \tag{29a}$$

$$b_1 = \left[\frac{1}{L} E_m \cos \omega t \;\; 0 \;\; 0 \;\; 0\right]^T. \tag{29b}$$

U zasićenom području gdje inače vrijedi relacija: In the saturated region where the following relation otherwise applies:

$$i_m = \frac{1}{L_{m2}} \Phi + \mathrm{sign}(\Phi)\left(\frac{1}{L_{m1}} - \frac{1}{L_{m2}}\right)\Phi_z \quad \text{za / for} \quad |\Phi| > \Phi_z, \tag{30}$$

dobiva se: the following is obtained:

$$\dot{x} = A_2 x + b_2, \tag{31}$$

gdje su:

where:

$$A_2 = \begin{bmatrix} -\dfrac{R}{L} & -\dfrac{1}{L} & 0 & 0 \\ \dfrac{1}{C} & 0 & -\dfrac{1}{C} & 0 \\ 0 & \dfrac{1}{L_1} & -\left(\dfrac{R_1}{L_1}+\dfrac{R_m}{L_1}\right) & \dfrac{R_m}{L_1 L_{m2}} \\ 0 & 0 & R_m & -\dfrac{R_m}{L_{m2}} \end{bmatrix}, \tag{31a}$$

$$b_2 = \left[\frac{1}{L}E_m\cos\omega t \;\; 0 \;\; \frac{R_m}{L_1}\operatorname{sign}(\Phi)\left(\frac{1}{L_{m1}}-\frac{1}{L_{m2}}\right)\Phi_z \;\; -R_m\operatorname{sign}(\Phi)\left(\frac{1}{L_{m1}}-\frac{1}{L_{m2}}\right)\Phi_z\right]^T. \tag{31b}$$

Implicitno trapezno pravilo primijenjeno na sustav $\dot{x} = \boldsymbol{A}_i x + bi, \;\; i = 1, 2$ daje iteracijsku vezu:

The implicit trapezoidal rule applied to the system $\dot{x} = \boldsymbol{A}_i x + bi, \;\; i = 1, 2$ yields the iteration expression:

$$x_{k+1} = \left[E - \frac{h}{2}A_i\right]^{-1}\left(\left[E + \frac{h}{2}A_i\right]x_k + \frac{h}{2}\left[b_i(t_k) + b_i(t_{k+1})\right]\right) \tag{32}$$

U posljednjoj relaciji sa $h$ označen je korak integracije i on je veoma problematičan za eksplicitne metode. Naime, da bi se osigurala stabilnost ovih postupaka korak se mora održati dovoljno malim da bi testovi stabilnosti bili zadovoljeni. Za Eulerovo pravilo je potrebno da korak integracije bude

In the previous expression, $h$ is designated as the integration step and it is highly problematic for explicit methods. In order to assure the stability of these procedures, the step should be kept sufficiently small in order to satisfy the stability tests. For Euler's rule, it is necessary for the integration step to be:

$$h \leq \min_i \left\{\frac{2\,\mathrm{Re}(\lambda_i)}{|\lambda_i|^2}\right\}, \tag{33}$$

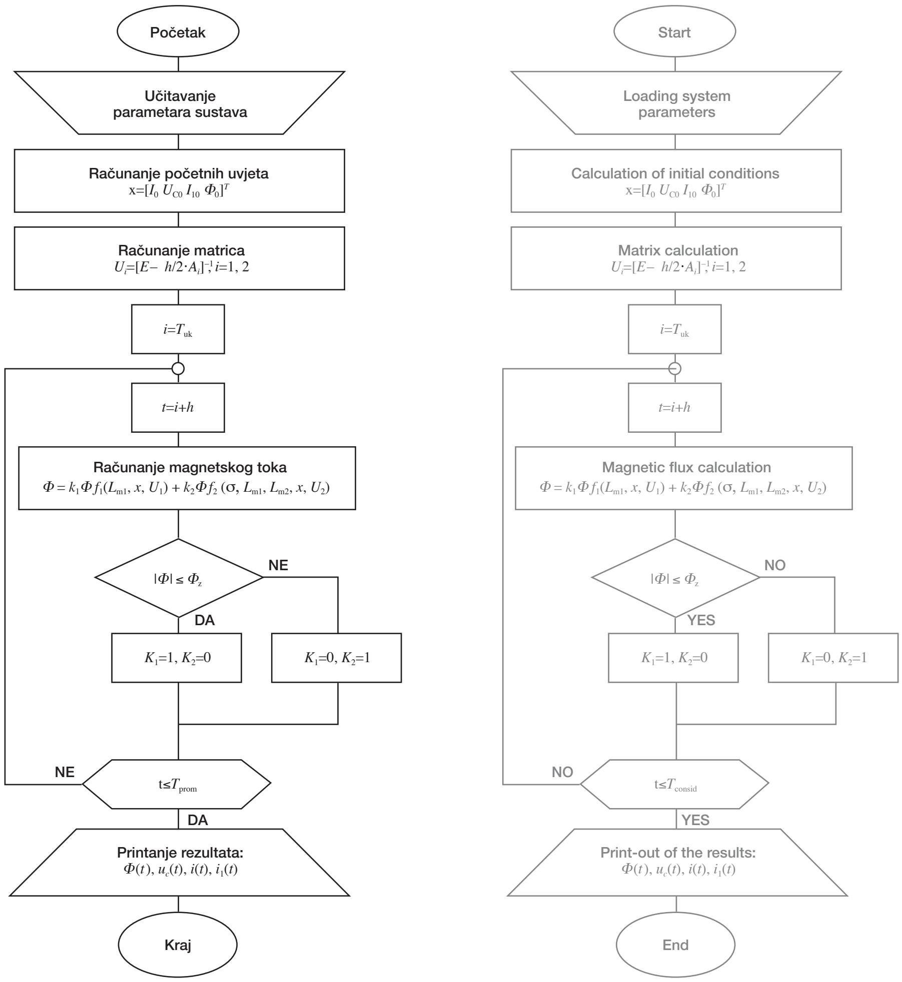
gdje su sa $\lambda_i$ označene sve svojstvene vrijednosti matrice $\boldsymbol{A}_i$. Za ovaj bi primjer već za nezasićeno područje korak bio:

where $\lambda_i$ denotes all the characteristic values of matrix $\boldsymbol{A}_i$. For this example, the step for the unsaturated region would be:

$$h \leq \frac{2 \cdot 4{,}575 \cdot 10^6}{4{,}575^2 \cdot 10^{12}} = 4{,}37 \cdot 10^{-7}. \tag{34}$$

Pri upotrebi implicitnog trapeznog pravila nije potrebno voditi računa o veličini koraka $h$.
Dakle, moguće je načiniti algoritam, slika 8, koji će prema (32) numerički rješavati sustav diferencijalnih jednadžbi (29) za $|\Phi| \leq \Phi_z$ i (31) za $|\Phi| > \Phi_z$.

When applying the implicit trapezoidal rule, it is not necessary to take the size of step $h$ into account. Therefore, it is possible to develop an algorithm, Figure 8 , which according to (32) will numerically solve the system of differential equations (29) for $|\Phi| \leq \Phi_z$ and (31) for $|\Phi| > \Phi_z$.




**Slika 8**
Razvijeni algoritam, potpuni model
**Figure 8**
Developed algorithm, complete model

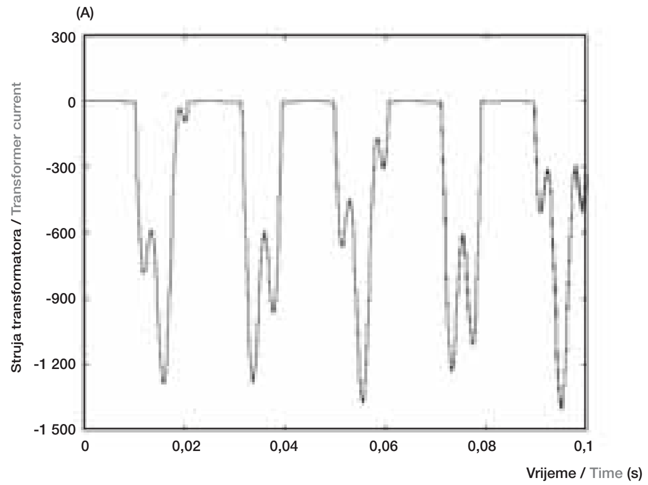
## 5 TEST PRIMJER

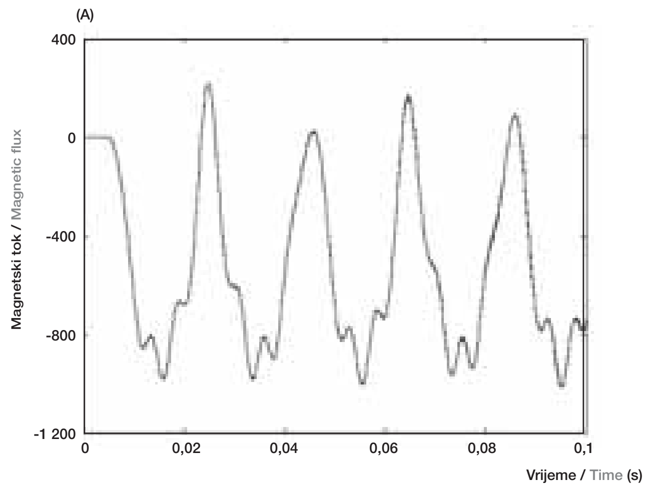
Programi dobiveni prema algoritmima sa slika 6 i 8 testirani su na MATLAB/Simulink/Power System Blockset (PSB), dio MATLAB-a za elektromagnetske tranzijente [19]. Parametri modela preuzeti su iz [8]. Rezultati simulacija dani su na slikama 9 i 10.

## 5 TEST EXAMPLE

The programs obtained according to the algorithms from Figures 6 and 8 have been tested using the MATLAB/Simulink/Power System Blockset (PSB), a part of MATLAB for electromagnetic transients [19]. The model parameters were taken from [8]. The simulation results are presented in Figures 9 and 10.

**Slika 9**
Pojednostavljeni model, $T_{uk} = 5$ ms, $\Phi_{rem} = 0$
**Figure 9**
Simplified model, $T_{uk} = 5$ ms, $\Phi_{rem} = 0$




Slika 9 pokazuje rezultate razvijenog algoritma koji uzima u obzir pojednostavljeni model uklapanja transformatora, bez prigušnih elemenata, poglavlje 3.

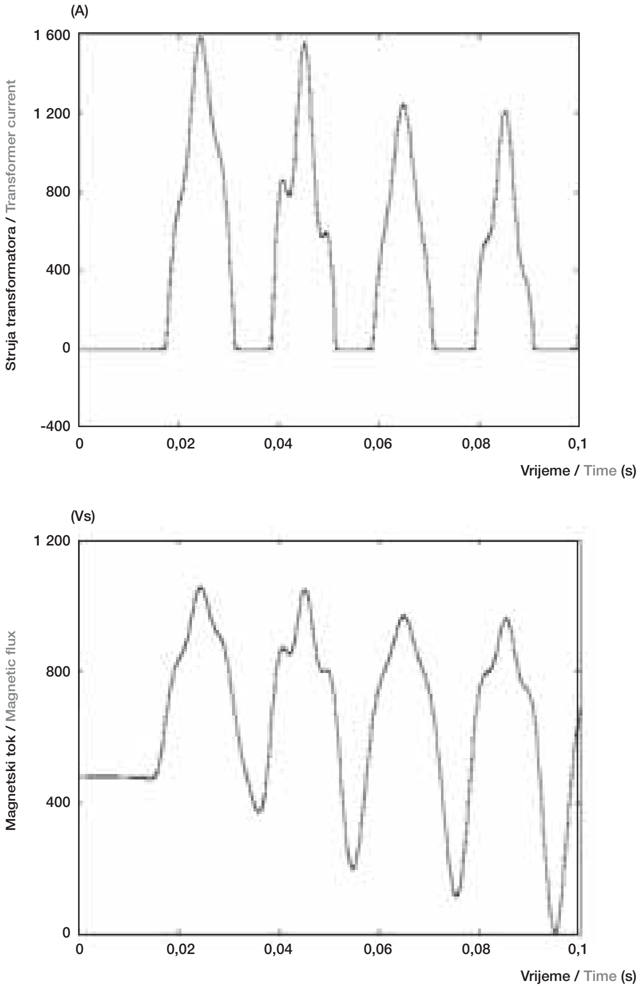
Slika 10 pokazuje rezultate razvijenog algoritma koji uzima u obzir potpuni model uklapanja transformatora, sa svim elementima, poglavlje 4. Na slici 10 je uvažen i remanentni magnetizam transformatora.

Može se zaključiti da se rezultati realiziranih programa u potpunosti podudaraju s programom PSB.

Figure 9 presents the results of the developed algorithm that takes the simplified model of transformer energization into account, without the damping elements, Chapter 3.

Figure 10 presents the results of the developed algorithm that takes the complete model of transformer energization into account, with all the elements, Chapter 4. In Figure 10, the transformer remnant magnetism has also been taken into account.

It can be concluded that the results of the realized programs are in complete agreement with the PSB program.




**Slika 10**
Potpuni model,
$T_{uk}$ = 15 ms,
$\Phi_{rem}$ = 0,8 $\Phi_{nom}$
**Figure 10**
Complete model,
$T_{uk}$ = 15 ms,
$\Phi_{rem}$ = 0,8 $\Phi_{nom}$

## 6 KOMPARACIJA S MJERENJIMA

Razvijeni program se može dalje generalizirati na modeliranje trofaznih transformatora, gdje su krivulje magnetiziranja predstavljene preko konačnog broja pravaca. Tada se vrijednosti struja magnetiziranja, po fazama, računaju iz formule [20]:

## 6 COMPARISON WITH MEASUREMENTS

A developed program can be further generalized for the modeling of three-phase transformers, where the magnetizing curves are represented by a finite number of straight lines. The values of the magnetizing current, according to phases, are then calculated from the following formula [20]:

$$i_{m(j)_k} = \frac{\Phi_{(j)}}{L_{m(j)_k}} - \mathrm{sign}(\Phi_{(j)}) \sum_{i=1}^{k-1} \Phi_{z(j)_i} \left( \frac{1}{L_{m(j)_i}} - \frac{1}{L_{m(j)_{i+1}}} \right). \qquad (35)$$

U posljednjoj relaciji su krivulje magnetiziranja, po fazama, dane s vektorima:

In the previous expression, the magnetizing curves, according to phases, are represented by vectors:

$$L_{m(j)} = \left[ L_{m(j)_1}, L_{m(j)_2}, \ldots, L_{m(j)_N} \right]^T, \quad (36)$$

$$\Phi_{z(j)} = \left[ \Phi_{z(j)_1}, \Phi_{z(j)_2}, \ldots, \Phi_{z(j)_N} \right]^T, \quad (37)$$

gdje su:

$j$ = 1, 2, 3 oznake faza,
$N$ = ukupni broj pravaca krivulje magnetiziranja.

Razvijeni algoritam je verificiran kompariranjem izmjerenih i simuliranih struja uklapanja neopterećenog trofaznog transformatora. Parametri trofaznog, trostupnog 2,4 kVA, 0,38/0,5 kV, Y-Y transformatora su:

- napon kratkog spoja $u_{k\%}$ = 3 %,
- djelatni otpor namota po fazi $R_{tr}$ = 1,5 Ω,
- rasipni induktivitet $L_{tr}$ = 1 mH,
- gubici u jezgri transformatora $R_m$ = 4 626 Ω.

Nelinearna krivulja magnetiziranja je predstavljena preko 13 pravaca, [20]. Pri modeliranju trostupnog transformatora uvažena je i nulta reaktancija $L_0$ = 15 mH [20].

Model transformatora [20], s pridodanom nultom reaktancijom prikazan je na slici 11.

where:

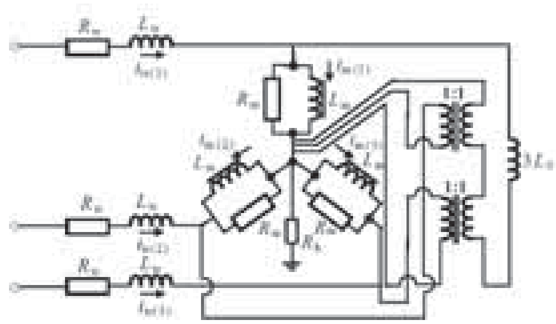
$j$ = 1, 2, 3 are phase designations,
$N$ = the total number of straight lines of the magnetizing curve.

The developed algorithm is verified by compairson between the measured and simulated inrush currents of the no-load three-phase transformer. The parameters of the three-phase three-legged 2,4 kVA, 0,38/0,5 kV, Y-Y transformer are as follows:

- short-circuit voltage $u_{k\%}$ = 3 %,
- effective resistance per winding phase $R_{tr}$ = 1,5 Ω,
- leakage inductance $L_{tr}$ = 1 mH,
- iron core losses $R_m$ = 4 626 Ω.

A nonlinear magnetizing curve is presented via 13 straight lines [20]. In the modeling of a three-legged transformer, zero reactance $L_0$ = 15 mH is taken into account [20].

A transformer model [20] with added zero reactance is presented in Figure 11.



**Slika 11**
Model trofaznog, trostupnog transformatora s pridodanom nultom reaktancijom
**Figure 11**
Model of a three-phase, three-legged transformer with added zero reactance

Izvor je modeliran s vektorom elektromotorne sile po fazama:

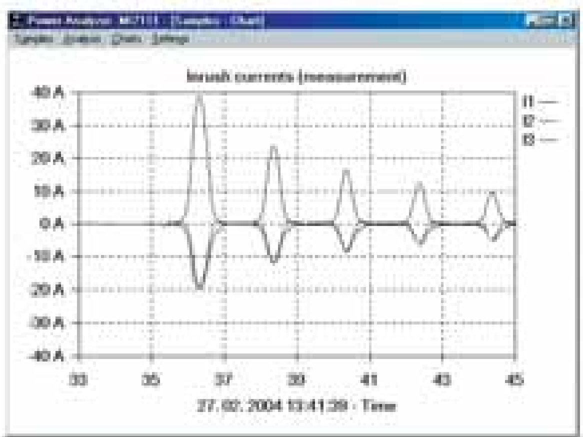
The source is modeled with a vector of the electromotive force for each phase:

$$E = \left[311\cos(\omega t - 34^\circ),\ 311\cos(\omega t + 86^\circ),\ 311\cos(\omega t + 206^\circ)\right]^T. \tag{38}$$

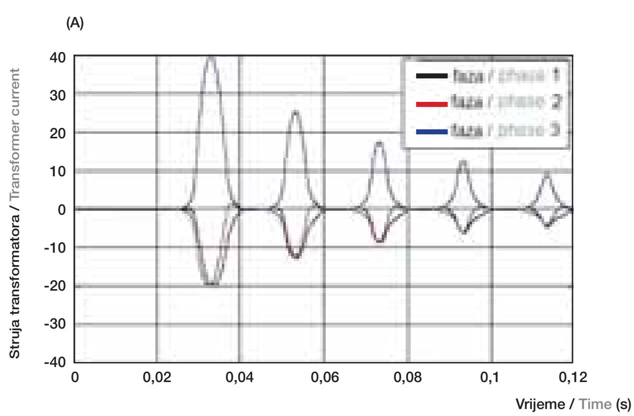
Rezultati mjerenja i simulacija dani su na slici 12.

The measurement and simulation results are presented in Figure 12.

a) Mjerenje / Measurement




b) Simulacija / Simulation




**Slika 12**
Struje uklapanja trofaznog transformatora: mjerenje i simulacija
**Figure 12**
Inrush current of a three-phase transformer: measurement and simulation

Analizom rezultata mjerenja i simulacija dolazi se do zaključka da maksimalna relativna pogreška, računata po tjemenim vrijednostima struje uklapanja tijekom svakog perioda, iznosi 3,56 %.

Through analysis of the measurement and simulation results, the conclusion is reached that the maximum relative error calculated according to the peak inrush current values during each period amounts to 3,56 %.

# 7 ZAKLJUČAK

U radu je opisan model transformatora primjenjiv u prijelaznim pojavama relativno niskih frekvencija. Za energetske transformatore velikih snaga pokazano je da se krivulja magnetiziranja kvalitativno može predstaviti preko dva pravca. Pokazane su granice upotrebe analitičkih metoda proračuna prijelaznih pojava u transformatorima. Za numeričko rješavanje sustava krutih diferencijalnih jednadžbi iskorišteno je implicitno trapezno pravilo. Razvijeni algoritam je moguće aplicirati u niskofrekvencijskim prijelaznim pojavama kao što su: uklapanje transformatora, ferorezonancija, ispad tereta, kvarovi transformatora itd. Na kraju je pokazan primjer upotrebe realiziranog algoritma na proračun prijelazne pojave uklapanja trofaznog trostupnog transformatora. Kompariranjem mjerenih i simuliranih struja uklapanja trofaznog transformatora ustanovljeno je da se pogreške nalaze u zadovoljavajućim granicama (maksimalno 3,56 %).

# 7 CONCLUSION

A transformer model applicable to relatively low frequency transient phenomena is described in the article. For power transformers with high power ratings, it was demonstrated that the magnetizing curve can be adequately presented with two straight lines. The limits for the use of analytical methods for the calculation of transient phenomena in transformers are presented. The implicit trapezoidal rule was used for the numerical solution of a system of stiff differential equations. The developed algorithm can be applied to low frequency transient phenomena such as transformer energization, ferroresonance, load switch-off, transformer faults etc. An example of the application of the developed algorithm was presented for the calculation of the transients that occur during the energization of a three-phase, three-legged transformer. Through comparison of the measured and simulated inrush currents of the three-phase transformer, it was established that the errors were within acceptable limits (a maximum of 3,56 %).

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Uredništvo primilo rukopis:
2007-07-10

Prihvaćeno:
2007-07-29

Manuscript received on:
2007-07-10

Accepted on:
2007-07-29

# DIJAGNOSTIČKI PREGLED RASPADA ELEKTROENERGETSKOG SUSTAVA NA OTOKU RODOSU

# DIAGNOSTIC REVIEW OF A BLACKOUT IN RHODES

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U radu se daje tehnička analiza jednog incidenta koji se dogodio 21. ožujka 2007. godine u 00:50 sati u noći i doveo do dvosatnog potpunog raspada elektroenergetskog sustava na otoku Rodosu. Analiza događanja temelji se na registriranim operativnim podacima kao i nalazima na terenu. Izvršena je tehnička analiza smetnji kako bi se utvrdili vjerojatni uzroci i čimbenici koji su pridonijeli pojavi smetnji. S obzirom da se radi o izoliranom sustavu koji je osobito je osjetljiv na poremećaje, ispitane su uloge zaštite sustava kao i kolebanja proizvodnje vjetroelektrana tijekom incidenta. Izvučeni su zaključci od praktičnog značenja i dane su preporuke korektivnih mjera koje valja provesti kako bi se u budućnosti spriječile takve smetnje.

A technical review of an incident on March 21, 2007 that began at 00:50 a.m. and led to a two-hour blackout of the island of Rhodes electric power system is presented with the complete sequence, including all the relevant registered operational data as well as the on-site field findings. A technical analysis of the disturbance was performed to determine the probable causes and factors that contributed to the duration of the disturbance. Since the system is an isolated one, it is particularly vulnerable to perturbations. The roles of system protection and wind power generation during the incident are examined. Conclusions of practical importance are drawn, including recommendations for corrective measures to be implemented for preventing disturbances of this kind from reoccurring in the future.

Ključne riječi: izolirani elektroenergetski sustav, nestanak struje
Key words: blackout, isolated electric power system

# 1 UVOD

Izolirani otočni elektroenergetski sustavi zanimljivi su s tehničkog stajališta jer pokazuju neke izrazite značajke. Ako je u takvim sustavima prisutan i visok stupanj proizvodnje vjetroelektrana, javlja se u određenim okolnostima veća osjetljivost na pogonske poremećaje.

Elektroenergetski sustav grčkog otoka Rodosa izolirani je sustav s ukupno 234 MW instaliranog kapaciteta termoelektrana (5 dizelskih, 2 parne i 4 plinske turbine) te 15 MW instalirane snage u vjetroelektranama. Međutim, zbog nekih tehničkih problema i karakteristika termoelektrana, stvarna snaga termoelektrana iznosi tek približno 192 MW. Godine 2006. proizvodnja u satu vršnog opterećenja iznosila je 192,6 MWh. To znači da sustav nije uvijek imao na raspolaganju rezervnu snagu.

U ovom se članku istražuje incident poremećaja sustava 21. ožujka 2007. godine koji je započeo u 00:50 sati u noći i doveo do dvosatnog raspada elektroenergetskog sustava na otoku Rodosu.

U vrijeme neposredno prije incidenta u pogonu su bili dva parna bloka (ATM 1 i ATM 2), svaki opterećen s 10 MW (rotirajuća rezerva svakog agregata 2 MW), dva dizelska bloka (D1 i D3): s opterećenjem 6 MW (rotirajuća rezerva 5 MW), ostala proizvodnja s 12 MW (rotirajuća rezerva 5 MW) te 12 MW vjetroelektrana. Vremenski uvjeti bili su loši i jamačno su odigrali određenu ulogu na početku incidenta. Na slici 1 dana je jednopolna shema sustava.

Smetnje u sustavu započele su asimetričnim trofaznim kratkim spojem bez zemljospoja. Taj je kvar uspješno uklonjen. Međutim, zbog nestabilnosti uzrokovane zaštitnim mehanizmima sustav se nije oporavio već je postupno gubio proizvodnju i izazivao značajnu redukciju opterećenja što je, nakon 2 minute i 45 sekundi od uklanjanja prvog kvara, konačno dovelo do potpunog raspada elektroenergetskog sustava.

# 1 INTRODUCTION

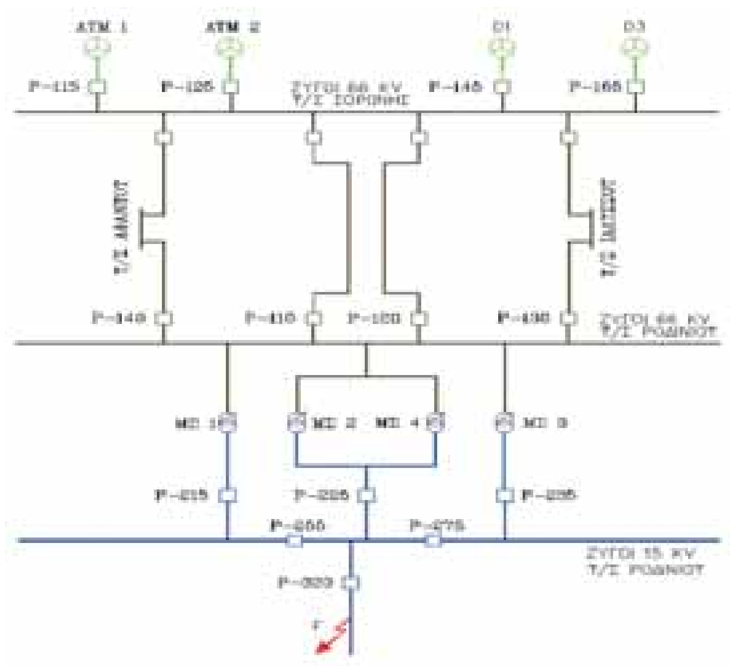
Isolated island power systems are of interest from the technical point of view because they exhibit notable characteristics. For example, when there is a high penetration of wind generation, there is greater vulnerability to operation perturbations under certain conditions.

The electric power system of the Greek island of Rhodes is an isolated system with 234 MW installed capacity of thermal plants (5 diesel, 2 steam and 4 gas turbines) plus 15 MW wind generation. However, due to some technical problems and the characteristics of the thermal generating plant, the actual thermal generation capacity is only about 192 MW. In the year 2006, the mean average hourly generation peaked at 192,6 MWh. This means that the system did not have appreciable reserve power at all times.

This article examines the system disturbance incident of March 21, 2007 that began at 00:50 a.m. and led to a two-hour blackout of the Rhodes Island Electrical Power System.

At the time just before the incident, the system was operating with 2 steam units (ATM 1, and ATM 2) with 10 MW production each (a spinning reserve of 2 MW each) and 2 diesel units (D1, and D3): one producing 6 MW (with a 5 MW spinning reserve) and the other generating 12 MW (with a 5 MW spinning reserve). At the same time, wind generation was 12 MW. A one-line diagram of the system is shown in Figure 1. The weather conditions were severe and played a definite role at the start of the incident.

The system disturbance began with an asymmetrical three-phase fault, not involving ground. This fault was successfully cleared. However, due to instabilities triggered by the protective mechanisms, the system never really recovered, gradually losing generation and causing significant load shedding, which finally led to a complete blackout lasting 2 minutes and 45 seconds after the initial fault had been cleared.




**Slika 1**
Jednopolna shema sustava na početku smetnje
**Figure 1**
One-line diagram of the system at the start of the fault

Kvar se dogodio na trafostanici Rhodini na distribucijskom vodu napajanom putem prekidača P-320 od 15 kV sabirnice, kako je prikazano na slici 1. Nakon gubljenja struje iz voda aktivirana je zaštita i otpušteni su prekidači P-320, P-255 i P-225. Zbog kvara je izgorio drveni stup distribucijskog voda te se kasnije morao zamijeniti. Vrijeme je bilo vrlo loše u trenutku kvara, pri čemu je jak vjetar raspršivao kapljice morske vode po izolatorima vodova, što je intenziviralo površinsko pražnjenje. Naknadnom analizom pronađen je srednji fazni vodič (u vodoravnom rasporedu od 3 faza) prekinut na jednom drvenom stupu. Isto se dogodilo s drugim stupom istog voda gdje su, osim prekinutog srednjeg vodiča, također bili razbijeni porculanski izolatori, najvjerojatnije kao posljedica struje zemljospoja. Taj je početni kvar konačno uklonjen oko 13 sekundi nakon što se dogodio. Međutim, 19 sekundi nakon uklanjanja kvara ispao je parni blok #1 a potom, 2 minute i 45 sekundi nakon uklanjanja kvara, i parni blok #2, što je rezultiralo raspadom elektroenergetskog sustava.

The fault occurred at the Rhodini substation on the distribution line fed through the breaker P-320 from the 15 kV bus, as shown in Figure 1. Following the fault, protection was activated and tripped the breakers P-320, P-255 and P-225. As a result of the fault, a wooden pole of the distribution line burned and had to be replaced later. The weather was severe at the time of the fault, with strong wind spraying sea water droplets over the line insulators, thereby increasing the likelihood of a flashover. Post-mortem examination found the jumper wire for the middle phase conductor (in a horizontal arrangement of the 3 phases) cut at another wooden pole of the same distribution line. The same thing also happened to another pole of the same line where, in addition to a broken middle jumper wire, its porcelain insulators were also broken. This would most likely imply that these were the results of the fault current. This initial fault was finally cleared at about 13 sec after it happened. However, 19 sec after the fault clearance, Steam Unit #1 was lost, and 2 min and 45 sec after the fault clearance Steam Unit #2 was lost, resulting in the blackout.

# 2 ANALIZA INCIDENTA

Kako sustavu SCADA u kontrolnom centru nedostaju neke važne funkcije bilo je moguće tek samo bilježenje pogonskih podataka u realnom vremenu, dok se u mnogim slučajevima događaju značajna zakašnjenja u bilježenju podataka. Iz ispitivanja zabilježenih događaja i podataka moguće je zaključiti kako je smetnja započela asimetričnim trofaznim kratkim spojem bez zemljospoja. Ovaj zaključak temelji se na vremenskim krivuljama izmjenične struje zabilježenih digitalnim relejima prekidača P-225 i P-255 (slika 2), koji su pokazivali nepostojanje struje zemljospoja. Moglo se također zamijetiti da impendancije kvara variraju s vremenom, upućujući na električno iskrenje kao uzrok. Oscilogrami 1 i 2 (slike 3 i 4) prikazuju napone na sabirnicama 66 kV na trafostanici Rhodini, odnosno struje na prekidaču 66 kV P-110 onako kako su se i razvijali. Naknadni vremenski oscilogrami 3 i 4 (slike 5 i 6) tu oscilaciju (frekvencije 100 Hz) jasnije prikazuju. Oscilacija se održava do kraja (kao što je razvidno iz oscilograma 5 (slika 7). To može značiti i da je automatskim regulatorima napona (AVR) potrebno podešavanje.

Iz oscilograma napona moguće je izračunati veličinu napona kao funkcije vremena, i to od nastanka kvara do potpunog pada napona, kako je prikazano na slici 8.

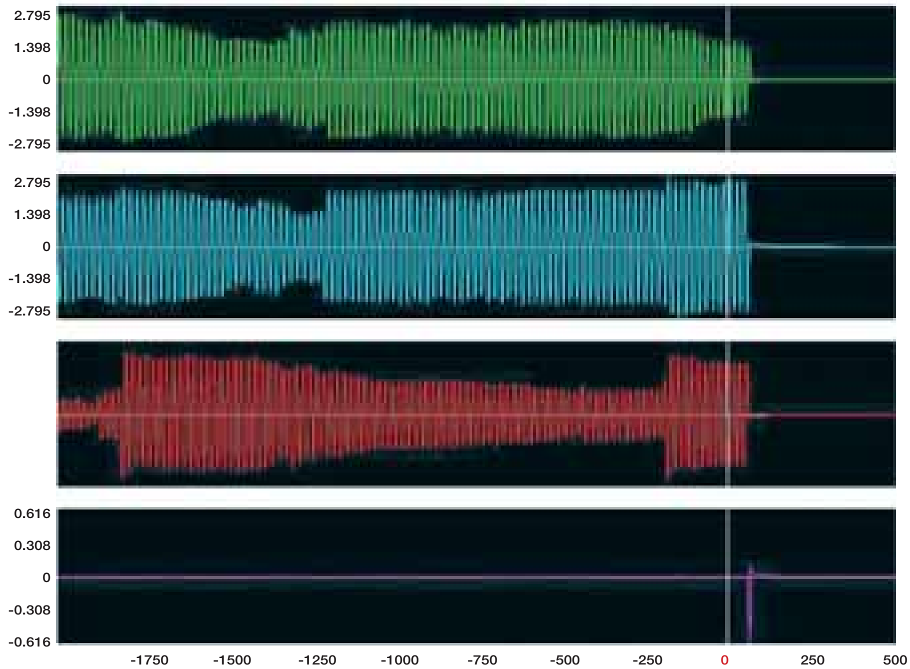
Tijekom smetnje zabilježene su promjene frekvencije širokog raspona. Relevantni podaci prikazani su na slici 9 na kojoj je vidljiva minimalna frekvencija od 47,7 Hz (2 s nakon početka smetnje) i maksimalna frekvencija od 54 Hz (16 s nakon početka smetnje).

# 2 INCIDENT ANALYSIS

At the outset, one should note that the SCADA at the Control Center leaves important functionalities to be desired. As a result, real-time registration of operation is only partially possible, while in many cases significant time delays occur in data registration. From examination of the registered events and data, one is able to see the following. The fault began as an asymmetrical three-phase fault, not involving the ground. This was evident from the time alternating current curves registered by the digital relays of the P-225 and
P-255 (Figure 2) breakers, which showed zero earth current. It could also be observed that the fault impedances varied randomly with time, suggesting that the electric-arcing of varying spans was the cause. Oscillograms 1 and 2 (Figures 3 and 4) show the voltages at the 66 kV buses at Rhodini and the currents at the 66 kV breaker P-110, respectively. These oscillograms show oscillation developing as time progresses. Subsequent time Oscillograms 3 and 4 (Figures 5 and 6) show this (100 Hz frequency) oscillation more clearly. This oscillation is sustained to the end (as seen in Oscillogram 5 (Figure 7). This could indicate that the automatic voltage regulators (AVR) need adjustments.

From the voltage oscillogram, one can calculate the voltage magnitude as a function of time, from the occurrence of the fault up to the voltage collapse, as shown in Figure 8.

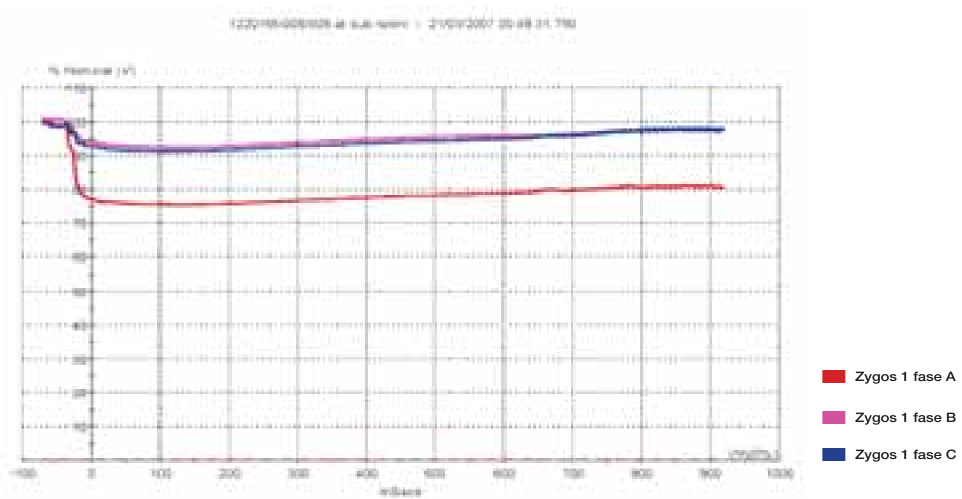
In the course of the disturbance, wide frequency swings were registered. The respective data are shown in Figure 9. In this figure, one can see the minimum frequency of 47,7 Hz (2 s after the start of the disturbance), and the maximum frequency of 54 Hz (16 s after the start of the disturbance).



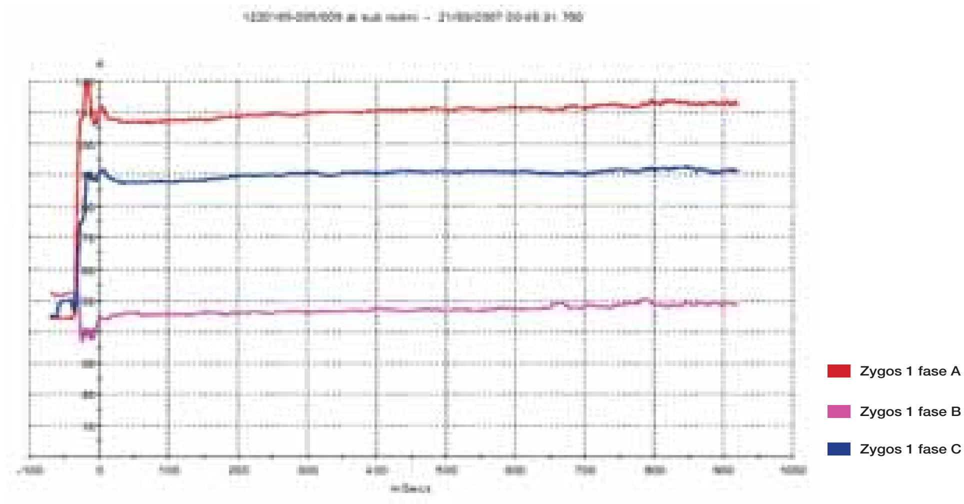

**Slika 2**
Vremenske krivulje izmjeničnih struja faza a, b, c i uzemljenja na prekidaču P-255
**Figure 2**
Time curves of the alternating currents of Phases a, b, c and ground at breaker P-255

Tijekom smetnje tri su se dodatna čimbenika pokazala ključnima. Podešenja podnaponske zaštite za park vjetroelektrana kao i za pojedinačne vjetrogeneratore imala su za posljedicu ispade generatora i gubitak proizvodnje iz vjetroelektrana (24 % ukupne proizvodnje). Podešenja zaštite poduzbudnih limitera dizelskih elektrana imala su za posljedicu njihov ispad. Ispadanje 40 MW opterećenja, zbog rada automatske podfrekvencijske zaštite, rezultiralo je u preostaloj snazi od 10 MW napajanoj iz parnog bloka #2 u zadnjim trenucima neposredno prije potpunog ispada.

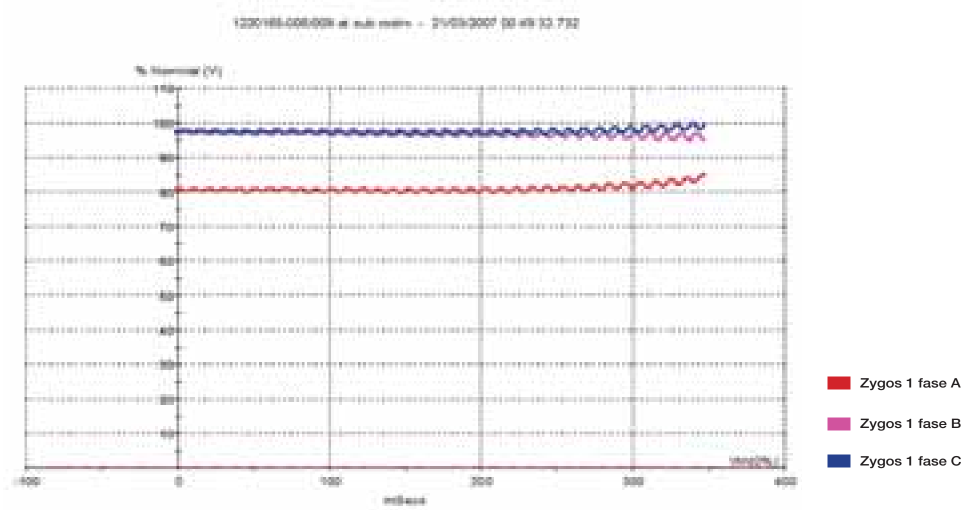
In the course of events, three additional factors were shown to be crucial. The under-voltage protection settings for the wind park and for the individual wind generators resulted in the loss of wind generation (24 % of the total generation). The under-excitation limiters protection settings of the diesel units resulted in the loss of those units. The shedding of 40 MW of load, due to the operation of the automatic under-frequency protection, resulted in a remaining load of 10 MW which was fed from Steam Unit #2 in the final moments just before the collapse.



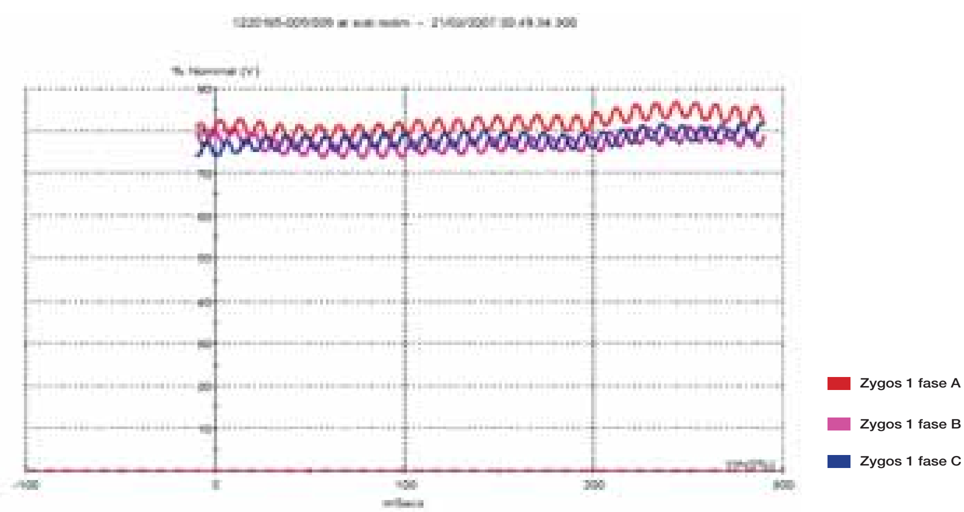

**Slika 3**
Oscilogram 1 – Naponi na sabirnici 66 kV na trafostanici Rhodini (početak gubljenja struje iz voda)
**Figure 3**
Oscillogram 1 – Voltages at the 66 kV bus at Rhodini (the fault begins)



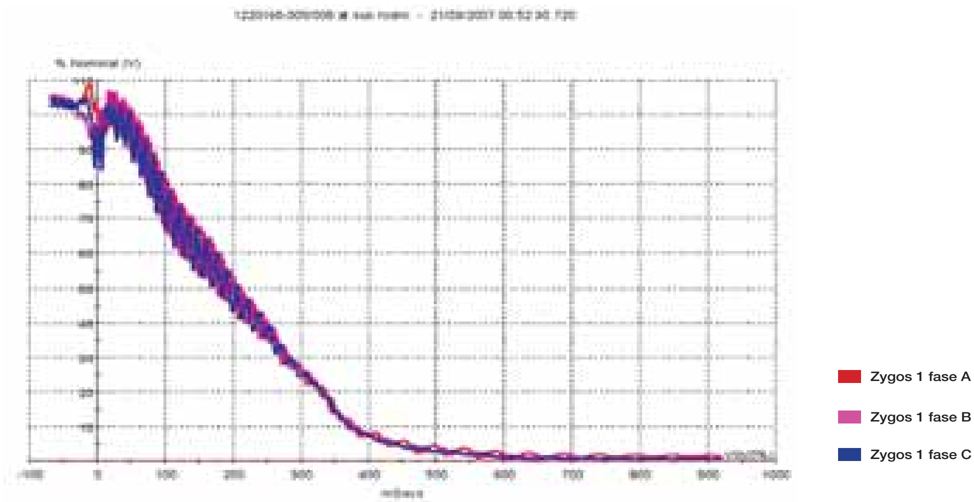

**Slika 4**
Oscilogram 2 – Struje zabilježene na prekidaču 66 kV P-110 na trafostanici Rhodini
**Figure 4**
Oscillogram 2 – Currents registered at 66 kV Breaker P-110 at Rhodini



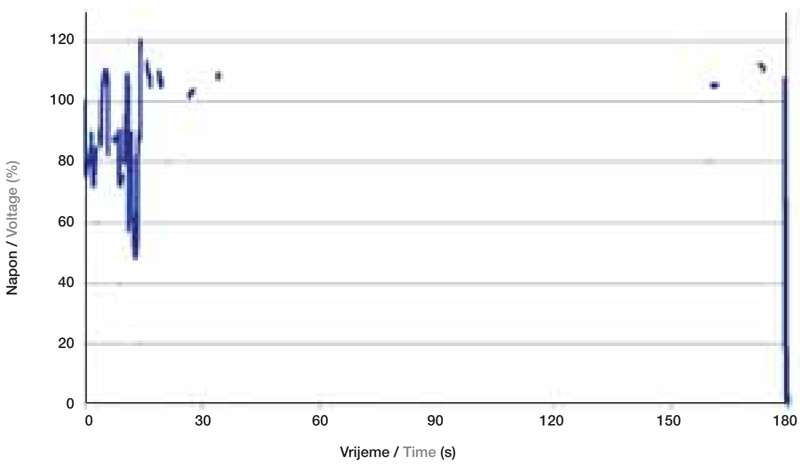

**Slika 5**
Oscilogram 3 – Naponi na sabirnici 66 kV na trafostanici Rhodini
**Figure 5**
Oscillogram 3 – Voltages at 66 kV bus at Rhodini



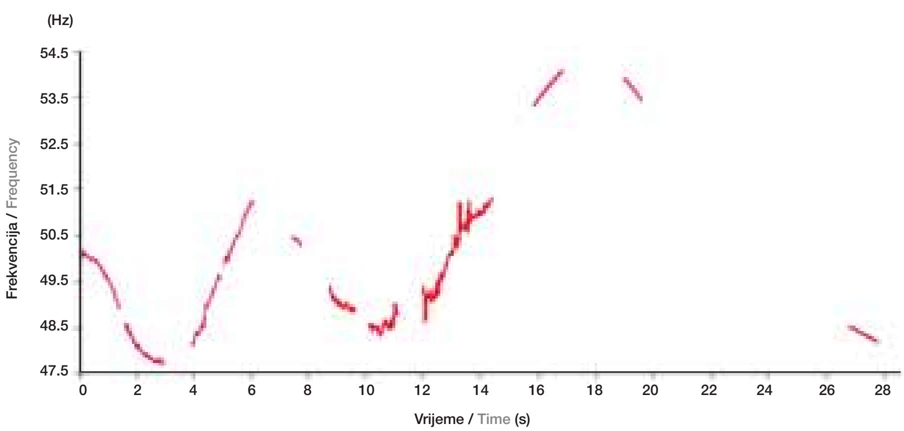

**Slika 6**
Oscilogram 4 – Naponi na sabirnici 66 kV na trafostanici Rhodini
**Figure 6**
Oscillogram 4 – Voltages at 66 kV bus at Rhodini




**Slika 7**
Oscilogram 5 – Napon na sabirnici 66 kV na trafostanici Rhodini (nestanak struje vidljiv na kraju)
**Figure 7**
Oscillogram 5 – Voltage at 66 kV bus at Rhodini (blackout seen at the end)




**Slika 8**
Varijacija napona na sabirnici 66 kV (u %) tijekom smetnje
**Figure 8**
66 kV bus voltage variation (in %) during the disturbance




**Slika 9**
Trend varijacije frekvencije zabilježen tijekom smetnje
**Figure 9**
Frequency variation trend registered during the disturbance

## 3 ZAKLJUČCI

Elektroenergetski sustav otoka Rodosa, kao jedan izoliran sustav, osjetljiv je na smetnje. Distribucijski sustav srednjenaponskih nadzemnih vodova u blizini obale također je osjetljiv na učinke morske soli koja negativno utječe na pouzdanost izolacije.

Osjetljivost proizvodnje vjetroelektrana na kolebanja u naponu mreže kao i ukupna zaštita sustava odigrale su ključnu ulogu u razvijanju poremećaja koji je doveo do raspada elektroenergetskog sustava.

Trenutačno se razmatra nadogradnja prijenosnog sustava na otoku Rodosu sa sadašnjih 66 kV na 150 kV što bi se trebalo realizirati u naredne dvije do tri godine. Osim izgradnje prijenosne mreže, potrebno je nadograditi i sustav SCADA te sustave zaštite.

## 3 CONCLUSIONS

As an isolated system, the Rhodes Island system is vulnerable to disturbances. The MV overhead line distribution system in the vicinity of the coast is also vulnerable to the effects of sea salts that adversely affect the reliability of insulation.

The sensitivity of wind generation to voltage swings as well as the overall system protection played a critical role in the development of the perturbation which led to the blackout.

In view of the fact that the transmission system on Rhodes Island is currently being considered for an upgrade from the present 66 kV to 150 kV, scheduled for the next two-to-three years, it is important that the SCADA system is upgraded as well. The protection scheme should also be upgraded.

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Uredništvo primilo rukopis:
2007-07-25

Prihvaćeno:
2007-09-27

Manuscript received on:
2007-07-25

Accepted on:
2007-09-27

# BAZA PODATAKA RELEJNE ZAŠTITE
# RELAY PROTECTION DATABASE

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U radu je prikazan razvoj baze podataka relejne zaštite kroz niz faza. U fazi planiranja baze sagledani su problemi u tipičnom odjelu relejne zaštite i utvrđeno je zašto razvijati bazu podataka. Potom je u fazi analize i specifikacije zahtjeva definirano za što će se baza koristiti. U fazi oblikovanja i izrade baze podataka definiran je njen logički, a potom i fizički model na računalu korištenjem sustava za upravljanje bazom podataka Microsoft Access koji je precizirao kako će baza podataka raditi. Na kraju je baza podataka uvedena u rad provjerom na stvarnim podacima te izobrazbom budućih korisnika. Prikazana baza podataka omogućava sistematizaciju, čuvanje i korištenje velikog broja podataka uz minimalnu redundanciju. Pored toga pruža podršku pri redovnom održavanju uređaja relejne zaštite, izdavanju radnih naloga, periodičkom izvještavanju itd. Bazi podataka relejne zaštite može pristupiti nekoliko korisnika s različitim ovlastima nad pojedinim objektima baze. Pravo pristupa određeno je korisničkim identitetom. Također je kreirana i posebna aplikacija za lakši pregled, ažuriranje i ispis podataka koji omogućava prikaz niza ranije pripremljenih komponenti baze podataka relejne zaštite. Osnovna namjena aplikacije je omogućiti korisniku korištenje pune snage Microsoft Access uz najmanje truda i minimum potrebnog znanja o tehnici baza podataka i sustavu za upravljanje bazom podataka.

The article presents the development of a relay protection database through a series of phases. In the planning phase of the database, problems in a typical relay protection department are examined and the reasons why a database should be developed are determined. Subsequently, during the phase of analysis and the specification of requirements, what the database will be used for is defined. In the phase of the formation and construction of the database, its logic is defined and then a physical model is prepared on a computer using the Microsoft Access database management system, which stipulates how the database will operate. The database is placed into operation and verified using actual data. Training is then provided for the future users. The database presented facilitates the systematization, storage and use of a large quantity of data with minimum redundancy. In addition, it provides support during the regular maintenance of relay protection equipment, the issuing of work orders, periodic reporting etc. The relay protection database can be accessed by several users with differing permissions for individual objects of the database. The right to access is defined by the user identity. Furthermore, a special application has been created to simplify searching updating and printing-out of data, which facilitates the display of a series of previously prepared components of the relay protection database. The basic purpose of the application is to allow the user to utilize the full power of Microsoft Access with a minimum of effort and a minimum of required knowledge about database technique and the system for database management.

Ključne riječi: baza podataka, elektroenergetski sustav, relacijski model podataka, relejna zaštita
Key words: database, electric power system, relational data model, relay protection

# 1 UVOD

Sustavi relejne zaštite u elektroenergetskom sustavu su iznimno važni i istodobno prilično kompleksni. U praksi se koristi puno elemenata različitih proizvođača, uređaji različite tehnološke generacije. Tipični odjeli relejne zaštite (npr. Odjel za zaštitu i mjerenja u HEP Operator distribucijskog sustava d.o.o.) koriste veliku količinu podataka iz različitih izvora čiji se broj neprestano povećava. Radi toga raste potreba za racionalnom i sigurnom pohranom niza podataka te njihovim svrsishodnim korištenjem od strane više korisnika. Primjena modernih informacijskih tehnologija u odjelima relejne zaštite, naročito znanja i tehnika baza podataka, ne samo da pruža veliku pomoć korisnicima, već sve više postaje nužnost.

Baze podataka do danas su najkompleksniji način organiziranja i korištenja pohranjenih podataka. Napredni sustavi za upravljanje bazom podataka kontroliraju složene strukture podataka i integriraju ih u jedinstveni sustav. Svrha sustava baze podataka jest pretvaranje niza podataka u korisne informacije prikazane u obliku pogodnom za korisnika.

Namjera ovoga rada je ukazati na mogućnosti primjene tehnike baze podataka u odjelima relejne zaštite, odnosno odgovoriti na pitanja zašto stvarati bazu podataka, zatim za što će se baza koristiti i na kraju prikazati kako organizirati bazu podataka radi zadovoljenja postavljenih zahtjeva.

# 1 INTRODUCTION

Relay protection systems in an electric power system are exceptionally important and at the same time fairly complex. In practice, many elements from various manufacturers are used as well as equipment from several technological generations. A typical relay protection department (e.g. the Department for Protection and Measurement at the HEP Distribution System Operator (HEP ODS d.o.o.) uses a large amount of data from various sources, which are constantly increasing. Therefore, there is a growing need for the rational and secure storage of data series and their appropriate use by a number of users. The application of modern information technologies in relay protection departments, particularly database knowledge and techniques, not only provides great assistance to users but is increasingly becoming a necessity.

Databases are still the most complex manner of organizing and using stored data. Advanced systems for database management control complex data structures and integrate them into a single system. The purpose of a database system is to transform a series of data into useful information, presented in a form that is suitable for the user.

The purpose of this article is to present possibilities for the application of database technique in relay protection departments, i.e. to answer the questions why a database should be created, what it will be used for and how to organize a database in order to meet the determined requirements.

# 2 NAMJENA BAZA PODATAKA RELEJNE ZAŠTITE

U odjelu relejne zaštite vrše se poslovi izbora vrste i mjesta ugradnje elemenata relejne zaštite, projektiranje, konfiguriranje i parametriranje releja (podešavanje releja), puštanje uređaja u pogon, zatim redovni i interventni pregledi uređaja u sustavu zaštite, održavanje uređaja itd. Za svaki relej i svaku njegovu funkciju potrebno je imati službenu dokumentaciju odnosno ispitne protokole s tehničkim podacima o releju, ali i vlastite podatke o mjestu ugradnje pojedinog releja i trenutačno postavljenim parametrima. Redovno i povremeno održavanje, ispitivanje i udešenje releja također zahtijeva popratnu dokumentaciju. Posao, tijekom niza godina, obično obavlja više ljudi s različitim pristupom pri formiranju potrebne tehničke dokumentacije, pisanju izvješća itd. Najčešće postoje formulari za upis podataka o nekom zaštitnom releju, no i formulari se povremeno mijenjaju i usklađuju. Također se elementi sustava

# 2 THE PURPOSE OF RELAY PROTECTION DATABASES

In a relay protection department, tasks are performed such as the selection of the types and sites for installing relay protection elements, designing, configuring and parametrizing relays, placing equipment into operation, regular and interventional inspections of equipment within the protection system, equipment maintenance etc. For every relay and each of its functions, it is necessary to have official documentation, i.e. testing protocols with technical data on the relay but also particular data on the installation site of an individual relay and the currently set parameters. Regular and periodic maintenance, testing and adjustment of the relay also require accompanying documentation. Over the years, this task is generally performed by several people with differing approaches to the formation of the necessary technical documentation, the writing of reports etc. Most commonly there are forms for data entry on a protective relay but the forms also change occasionally and are zaštite povremeno mijenjaju novijim uređajima, ponekad elementi sustava zaštite mijenjaju mjesto ugradnje ili im se udešene vrijednosti postavljaju na nove iznose. Sve skupa nerijetko rezultira vrlo šarolikom i nesređenom dokumentacijom. Za određeno izvješće često se postavlja pitanje da li je to izvješće posljednje ili postoji neko novije. Odjeli relejne zaštite, očito je, barataju s velikim brojem različitih podataka. Opseg tih podataka se neprestano povećava.

Temeljni cilj pri planiranju baze podataka relejne zaštite bio je stvoriti bazu podataka koja će pomoći korisniku u rješavanju navedenih problema. Veliki broj podataka koji će se čuvati u toj bazi već sada postoje na papiru u raznim formama. Uz to što ih treba sistematizirati i pravilno skladištiti, korisniku treba omogućiti dobivanje izvješća jednaka onima na kakve su već navikli u dosadašnjem radu. Analizom poslovnih procesa u odjelu zaštite došlo se do osnovnih informacijskih zahtjeva na bazu podataka:

– sistematizacija podataka zaštitnih uređaja, s obzirom da se koriste zaštitni uređaji različitih tehnoloških generacija i različitih proizvođača. Uređaji novije generacije obično imaju mnogo veće mogućnosti i mnogo veći skup podataka kojim su definirani od uređaja starije generacije,
– čuvanje niza podataka o zaštitnim uređajima na jednom mjestu u računalu. U bazu podataka treba pohraniti i statičke podatke o elementima zaštite kao tehničke podatke pojedinih uređaja, mjesto ugradnje pojedinih uređaja i sl. te dinamičke podatke o trenutačnom udešenju zaštite, izvršenom ispitivanju,
– evidencija dostupnih podataka i onih zaštitnih uređaja koji trenutačno nisu u pogonu, već su u remontu ili na skladištu,
– posjetnik i podrška pri redovnom održavanju i izdavanju radnih naloga,
– mogućnost uvida u različite skupine podataka i mogućnost ispisa različitih unificiranih izvješća od strane više korisnika različitog profila u odjelu relejne zaštite,
– mogućnost unosa, brisanja i izmjene podataka od strane jednog ovlaštenog korisnika.

Prilikom kreiranja baze podataka nametnuli su se i dodatni zahtjevi i ograničenja:

– baza podataka relejne zaštite mora biti jednostavna za korištenje odnosno potrebni razina znanja korisnika o tehnikama baza podataka te načinu pretraživanja i čuvanja podataka mora biti što niži. Zbog toga, a i zbog važnosti pohranjenih podataka, struktura i integritet podataka moraju biti na visokoj razini,

coordinated. Furthermore, elements of the protection system are periodically replaced by new equipment. Sometimes elements of the protection system are installed in different sites or their values are set to new levels. All of this not infrequently results in a lack of uniformity and highly disorganized documentation. For a specific report, the question is frequently asked whether the report is the most recent or if a newer one exists. Relay protection departments obviously deal with a large quantity of varied data. The range of these data is constantly increasing.

The fundamental goal in the planning of a relay protection database was to create a database that would help the user solve these problems. The great quantity of data that will be stored in the database already exists on paper in various forms. In addition, they must be systematized and stored in an orderly manner. The users must be able to obtain reports identical to those to which they have become accustomed in their work thus far. Analysis of the operational processes in the protection department resulted in the basic information requirements for the database:

– systematization of the data of the protection equipment, since protection equipment of various technological generations and various producers is used. Equipment from more recent generations generally has much greater possibilities and a much larger group of data, in contrast to the equipment of older generations,
– storage of a large amount of data on protection equipment in one place in the computer. In the database, it is also necessary to store static data on the elements of protection such as technical data on individual devices, the installation site of individual devices etc., and dynamic data on real-time protection settings and testing performed,
– records of available data on protective devices that are currently not in operation but are being repaired or stored in a warehouse,
– reminder and support for regular maintenance and the issue of work orders,
– the possibility of inspecting various groups of data and the possibility of printing out various uniform reports by several users of differing profiles in the relay protection department,
– the possibility of entering, deleting and changing data by an authorized user.

When creating the database, additional requirements and limitations have been imposed:

– the relay protection database must be simple to use, i.e. the required level of user knowledge regarding database techniques, searches and data storage must be kept to a minimum. Therefore and due to the importance of the stored data, the data structure and integrity must be at a high level,

– česti problem sličnih baza podataka relejne zaštite je redovno održavanje zbog velikog broja različitih komponenti baze (tablica, upita, izvješća) prilagođenih raznim vrstama i generacijama releja [1]. O ovom problemu također treba voditi računa prilikom dizajniranja baze,
– podaci pohranjeni u bazi također mogu služiti nizu aplikacijskih programa koji se koriste u odjelima zaštite pri proračunu raznih parametara elemenata sustava relejne zaštite (npr. proračunu kratkog spoja u elektroenergetskoj mreži) i sl. Pripremu podataka za aplikacijske proračune moguće je automatizirati koristeći dodatne programske rutine za povezivanje i prilagođene podataka iz baze i aplikacijskih programa [2]. Također je moguće oko baze podataka izgraditi cijeli sustav za rukovanje podacima zaštitnih uređaja, proračunavanje i analizu kvarova, postavljanje parametara releja, provjeravanje, simulaciju itd. [3], [4] i [5]. U ovoj fazi razvoja prikazane baze podataka nije predviđeno automatsko povezivanje aplikacijskih proračuna s podacima u bazi što značajno smanjuje informacijske zahtjeve te količinu potrebnih podataka,
– opseg podataka koje će baza obuhvatiti i prava pristupa određenim skupinama podataka treba prilagoditi postojećoj organizacijskoj strukturi odjela relejne zaštite, a također mjestu odjela relejne zaštite u organizacijskoj shemi cjelokupnog poduzeća. Informacijski zahtjevi koji su postavljeni na bazu podataka relejne zaštite u jednom tipičnom odjelu relejne zaštite, bar u ovom trenutku, nisu obuhvatili i nekakve pomoćne procese kao vođenje knjigovodstva i izdavanje knjigovodstvenih izvješća, proračun amortizacije pojedine opreme, obavljanje financijskih transakcija i slično.

## 3 MODELIRANJE PODATAKA

Modeliranje podataka je proces koji počinje analiziranjem informacijskih zahtjeva, a završava izgradnjom baze podataka [6] i [7]. Postupnim razvojem i transformacijom modela podataka kroz tri razine, što je uobičajeni postupak pri modeliranju podataka, došlo se do realizacije konačnog implementacijskog modela na računalu i stvaranja baze podataka relejne zaštite.

### 3.1 Konceptualni model podataka

Sukladno zahtjevima koji su postavljeni na bazu podataka u prvom koraku, razvijen je konceptualni model tipa entiteti-veze. Model tipa entiteti-veze jedan je od najčešće korištenih modela podataka treće generacije zato što raspolaže sa semantički

– a frequent problem with similar relay protection databases is regular maintenance due to the large number of various base components (tables, queries and reports) adapted to various types and generations of relays [1]. This problem must also be taken into account when designing the database,
– data stored in the base can also be used in a series of application programs employed by protection departments for the computation of various parameters of the relay protection system elements (e.g., calculation of a short circuit in the electric power network). Preparation of data for calculation applications can be automated by using additional program routines for linking and adapting data from the base and – application programs [2]. Furthermore, it is possible to construct an entire system around the database for the data management of protective equipment, calculation and analysis of faults, establishment of relay parameters, verification, simulation etc. [3], [4] and [5]. In this phase of the development of the database presented, automatic linking of the application software with data in the base has not been anticipated, thereby significantly reducing the information requirements and the quantity of data needed,
– the range of data that the base will cover and the right to access certain groups of data should be adjusted to the existing organizational structure of the relay protection department and the position of the relay protection department within the organizational schema of the entire enterprise. Information requirements placed upon the relay protection database in a typical relay protection department, at least at the moment, do not cover any auxiliary processes such as bookkeeping and issuing bookkeeping reports, calculation of the depreciation of individual equipment items, performance of financial transactions etc.

## 3 DATA MODELING

Data modeling is a process that begins with the analysis of information requirements and ends with the construction of a database [6] and [7]. The progressive development and transformation of a data model through three levels, which is the customary approach in data modeling, resulted in the implementation of the model on the computer and the creation of the relay protection database.

### 3.1 Conceptual data model

Based upon the requirements established for the database in the first step, a conceptual model of the entity-relationship type was developed. A model bogatim, prirodnim i korisniku bliskim konceptima, lako se transformira u klasične komercijalne modele, a prikladan je i za daljnje projektiranje baze podataka. Pri izradi modela podataka entiteti-veze vodilo se računa da podaci budu međusobno neovisni te da se jedan podatak nalazi samo na jednom mjestu. Na ovaj način model podataka može se graditi modularno, a iz modela podatka mogu se izlučivati podmodeli.

Tijekom modeliranja podataka također se vodilo računa o tome da je ovo samo jedan projekt, odnosno jedan podsustav unutar većeg globalnog modela podataka. Stoga se težilo strogom poštivanju pravila pri oblikovanju podataka kako bi se kasnije omogućila razmjena podataka drugim aplikacijama [8] i [9]. Cilj strateškog planiranja velikih informacijskih sustava i jest podjela sustava na dijelove koji se mogu realizirati malim projektima autonomno te relativno stabilna infrastruktura, u kojoj se manji, modularno projektirani podsustavi lako mogu povezati.

Tijekom izrada modela entiteti-veze najprije su definirani tipovi entiteta (energetski objekt, postrojenje, polje, strujni transformator, jezgra strujnog transformatora itd.) i njihovi tipovi atributa (funkcija polja, proizvođač strujnog transformatora, nazivna struja jezgre strujnog transformatora itd.) odnosno uočeni su i razlučeni entiteti i atributi. S obzirom da su neki entiteti grupirani (klasificirani) prema zajedničkim svojstvima izvršena je preraspodjela entiteta prema klasifikacijskim strukturama. Potom su definirane veze među entitetima i njihove karakteristike. Na kraju je nekoliko podmodela (podmodel energetskog transformatora, podmodel mjernih transformatora itd.) objedinjeno u zajednički model podataka tipa entiteti-veze.

### 3.2 Logički model podataka

Kada je konceptualni model zadovoljio postavljene zahtjeve, postupkom logičkog modeliranja pretvoren je u relacijski model podataka. Relacijski model podataka je izabran za logički model s obzirom da je to najpopularniji model komercijalnih sustava za upravljanje bazom podataka, a struktura modela je jednostavna. Dobivena logička shema baze podataka je provjerena prema zahtjevima korisnika.

Dio sheme relacijske baze podataka prikazan je na slici 1. U relacijama prikazanim na slici vidi se samo dio atributa kako slika ne bi bila prevelika. Model podataka je prilično složen s obzirom da se u praksi koristi niz različitih vrsta zaštita, a svaka opet više različitih tipova uređaja i različitih generacija izvedbe. Uz identifikacijske i opisne podatke, u model podataka integrirane su razne

of the entity-relationship type is one of the most frequently used third-generation data models because it employs semantically rich, natural and user-friendly concepts; can easily be transformed into classical commercial models and is suitable for the further design of a database. In developing the entity-relationship data model, it was stipulated that the data would be mutually independent and each data entry would be located in only one place. In this manner, the data model could be built modularly and submodels could be extracted.

During data modeling, it was taken into account that this is only one project, i.e. one subsystem within a larger global data model. Therefore, there is a tendency to respect rules more strictly when forming data to facilitate data exchange with other applications in the future [8] and [9]. The goal of the strategic planning of a large information system is the division of the system into parts, which can be achieved autonomously with small projects and a relatively stable infrastructure, within which smaller, modularly designed subsystems can be easily linked.

During the preparation of an entity-relationship model, first of all the types of entities (power system facilities, bays, current transformer, current transformer core etc.) are defined and their attributes (bay function, current transformer manufacturer, rated current of the current transformer core etc.), i.e. entities and attributes are noted and differentiated. Since some entities are grouped (classified) according to common properties, the entities were reconfigured according to the classification structures. Then the relationships among the entities and their characteristics were defined. Finally, several submodels (a submodel of a power transformer, a submodel of the measurement transformers etc.) were combined into a common data model of the entity-relationship type.

### 3.2 Logic Data Model

When a conceptual model has met the established requirements, it is transformed into a relational data model through the procedure of logical modeling. A relational data model has been chosen for the logic model because it is the most popular model used in commercial systems for database management, and the model structure is simple. The logic schema obtained of the database is verified according to user requirements.

Part of the schema of the relational database is presented in Figure 1. In the relationships shown in the figure, only a part of the attributes are seen so that the figure is not too large. The data model is fairly complex because a series of various types of slike (npr. jednopolne sheme), dijagrami i sl. Prikazani logički model podataka je još uvijek neovisan od konkretnog sustava za upravljanje bazom podataka.

### 3.3 Fizički model podataka

U posljednjoj fazi modeliranja podataka logički model podataka postupkom fizičkog modeliranja pretvoren je u fizički model i realiziran na računalu pomoću sustava za upravljanje bazom podataka Microsoft Access 2000. Prilikom izrade fizičkog modela velika pažnja je posvećena osiguranju integriteta podataka, a time stabilnosti i pouzdanosti buduće baze podataka u radu. Fizičko modeliranje je, uz određivanje formata fizičkog zapisa svih atributa definiranih u prethodnoj fazi (izbor vrste podataka i alokacija prostora), obuhvatilo definiranje niza kontrola koje pridonose minimalizaciji pogrješaka kod unosa podataka, indeksiranje pojedinih atributa radi kasnijeg bržeg i sigurnijeg pretraživanja. Procedure za kontroliranje ispravnost unesenih podataka provjeravaju da li su podaci unutar određenih graničnih vrijednosti kod podataka gdje je ta ograničenja moguće definirati, za neke podatke pružaju korisniku listu mogućih vrijednosti s tim da mu nekad dozvoljavaju i drugi izbor, a nekad ne. Za podatke, gdje je to bilo potrebno, definirane su maske za unos, nekim podacima su odmah upisane pretpostavljene vrijednosti koje se kasnije mogu promijeniti itd. Realizacijom fizičkog modela na računalu nastala je baza podataka relejne zaštite.

Microsoftov sustav za upravljanje bazom podataka odabran je iz dva razloga:

- Access 2000 (i novije verzije) prema svojim mogućnostima i popularnosti danas spada među vodeće programe za baze podataka na PC platformama,
- ako podaci nadrastu mogućnosti Accessa 2000 posebnom procedurom ugrađenom u Accessu 2000 lako ih je premjestiti na Microsoft SQL Server koji je dovoljno snažan za gotovo sve zahtjeve.

Performanse koje pruža Access 2000 sasvim su dostatne da zadovolje zahtjeve koji su u početku postavljeni na ovu bazu podataka [10] i [11]. Ukoliko se u budućnosti postave stroži zahtjevi na sustav za upravljanje bazom podataka kao veći opseg podataka, više korisnika, više istodobnih transakcija, poboljšana sigurnost itd., baza se može proširiti na SQL Server. Također, ako se ukaže potreba za integriranjem ove baze podataka s drugim bazama, mogućnost prelaska na Microsoft SQL Server verziju može biti od velike koristi.

protection are used in practice, and for each there are several different types of equipment of different generations. In addition to the identification and descriptive data, various figures are integrated into the data model (e.g. single-pole schemata), diagrams etc. The logic data model shown is still independent from the concrete database management system.

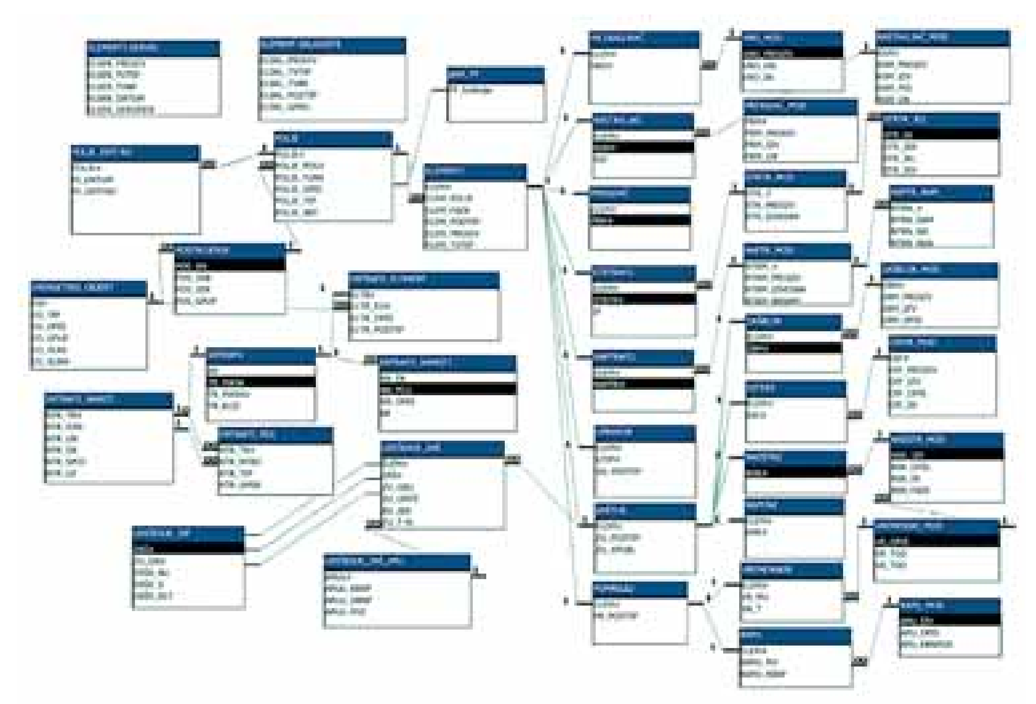
### 3.3 Physical Data Model

In the final phase of data modeling, the logic data model is transformed into a physical model through the procedure of physical modeling and realized on a computer using the Microsoft Access 2000 database management system. During the development of the physical model, great attention has been devoted to assuring the integrity of the data and, thereby, the stability and reliability of the future database in operation. Physical modeling, in addition to the determination of the format for the physical record of all the attributes defined in the previous phase (the selection of the types of data and the allocation of space), is the definition of a series of controls that contribute to minimizing errors in data entry and the indexing of individual attributes to facilitate more rapid and dependable searches later. The procedures for controlling the accuracy of the data entered verify whether the data are within the specified limit values for data where this limit can be defined. For some data, the user is offered a list of possible values. Sometimes another choice is permitted and sometimes not. Where necessary, data entry forms are defined and the assumed values for some data are entered immediately, which can be changed later etc. With the implementation of the physical model on the computer, a relay protection data base was created.

The Microsoft database management system was chosen for two reasons:

- Access 2000 and newer versions are among the leading database programs on PC platforms today, in terms of their possibilities and popularity.
- if the data outgrow the capabilities of Access 2000, a special procedure installed in Access 2000 makes it is easy to transfer them to a Microsoft SQL Server that is sufficiently powerful for nearly all requirements.

The performance provided by Access 2000 is fully sufficient to meet the requirements established at the beginning for this database [10] and [11]. If stricter requirements are set in the future on the system for database management such as a larger range of data, more users, more simultaneous transactions, improved security etc., the base can be extended to the SQL Server. Furthermore, if the need is demonstrated for the integration of this database with other bases, the possibility for transfer to the Microsoft SQL Server version could be very useful.



**Slika 1**
Dio relacijske sheme baze podataka
**Figure 1**
Part of the relationship schema of the database

## 4 SIGURNOST BAZE PODATAKA RELEJNE ZAŠTITE

Sustav za upravljanje bazom podataka MS Access 2000 nudi nekoliko sigurnosnih opcija za očuvanje integriteta i tajnosti podataka koje su iskorištene pri kreiranju baze podataka relejne zaštite. Sigurnost na razini korisnika kombinira korisnike, radne grupe i dozvole na razini objekta za potporu ograničenom pristupu različitim dijelovima baze podataka. Kod pokretanja programa MS Access 2000 potrebno je unijeti korisničko ime i lozinku za definiranje korisničkog identiteta. Korisničko ime je povezano sa skupom dozvola koje određuje što korisnik može raditi nad pojedinim objektima baze kad se baza podataka otvori. U bazi podataka relejne zaštite definirane su tri grupe korisnika s različitim pravima:

- administrator baze - ima mogućnost izmjene dizajna i strukture baze te pregled i ažuriranje podataka u bazi,
- ovlašteni korisnik - ima mogućnost pregleda i izmjene podataka u bazi, ali nema mogućnost izmjene dizajna i strukture baze,
- obični korisnici - imaju samo mogućnost pregleda podataka.

Grupne ovlasti administratora baze i grupne ovlasti ovlaštenog korisnika ima po jedan korisnik dok ovlasti grupe obični korisnici ima više korisnika.

## 4 SECURITY OF THE RELAY PROTECTION DATABASE

The MS Access 2000 database management system offers several security options for safeguarding the integrity and secrecy of the data that are used in creating a relay protection database. Security at the user level encompasses users, work groups and permission at the level of the object to support limited access to various parts of the database. When starting the MS Access 2000 program, it is necessary to enter the user name and password for the definition of the user's identity. The user's name is linked with a set of permissions that determine what a user can do regarding individual objects of the base when the database opens. In the relay protection database, three groups of users with different rights are defined:

- the base administrator can change the design and structure of the base as well as view and update the data in the base,
- the authorized user can view and change data in the base but cannot change the design and structure of the base,
- the ordinary users can only view data.

The administrator group permissions and the user group permissions have one user each while permissions for the group of ordinary users are held by several users. Individual users in this group can be

Pojedinim korisnicima u ovoj grupi mogu se dati dodatne ovlasti nad nekim objektima baze kao na primjer mogućnost dodavanja podataka u neke tablice, ali bez mogućnosti brisanja ili izmjene postojećih podataka. Ovlasti grupa i korisnika nisu trajno definirane jer administrator baze podataka u svakom trenutku može ovlasti promijeniti ili dodati novog korisnika. Prirodno je da ovlasti ovlaštenog korisnika dobije osoba u odjelu zaštite zadužena za ispravnost unesenih podataka.

Baza podataka relejne zaštite je, za sada, zamišljena i prilagođena čuvanju i održavanju na jednom PC računalu (najvjerojatnije računalu ovlaštenog korisnika) uz mogućnost korištenja kopija za pregled na drugim računalima. Također je moguće dozvoliti rad nad bazom podataka s drugih računala u lokalnoj mreži. Tada se postavkom lokalne mreže definiraju računala s kojih se može pristupiti i s kakvim ovlastima (samo čitanje ili čitanje uz mogućnost ažuriranja i sl.).

Uz sigurnost na razini korisnika uvedena je i dodatna zaštitna mjera u obliku lozinke na bazu podataka. Ovu lozinku se ne smije brkati s korisničkom lozinkom pri pokretanju MS Accessa 2000. Dakle za rad s bazom podataka relejne zaštite nakon prijavljivanja korisnika (upis korisničkog ime i lozinke) još je potrebno unijeti i lozinku baze podataka relejne zaštitite kao drugu razinu sigurnosti.

## 5 APLIKACIJA ZA PREGLED, AŽURIRANJE I ISPIS PODATAKA

Sustav za upravljanje bazom podataka MS Access 2000 uz razne mogućnosti pri konstrukciji tablica i upisu podataka nudi niz vrlo moćnih alata za pregledavanje baze podataka, postavljanje različitih upita, kreiranju izvješća i njihovo prilagođavanje ispisu na papir. Za uspješno korištenje baze podataka i svih prednosti koja ona pruža nužno je određeno znanje iz tehnike baze podataka te poznavanje rada s programom MS Access. Program MS Access također nudi niz alata za automatizaciju rada i brz pristup često korištenim dijelovima baze bez poznavanja pojedinih komponenti i njihovih međusobnih odnosa. Koristeći te alate kreirana je posebna aplikacija za lakši pregled, ažuriranje i ispis podataka iz baze relejne zaštite s mogućnošću aktiviranja niza pripremljenih upita, ekranskih obrazaca i izvješća. Aplikacija u svom radu koristi i ostale komponente baze podataka kao makronaredbe i programske rutine napisane u programskom jeziku Microsoft VBA (Visual Basic for Applications) kako bi se u potpunosti iskoristila snaga Accessa. Osnovna namjena aplikacije

given additional permissions for some of the database such as, for example, the option of adding data to some tables, but without the option of deleting or changing existing data. Group and user permissions are not permanently defined because the administrator of the database can change permissions at any moment or add new users. It is natural for the permission of an authorized user to be obtained by a person in the security department in charge of the accuracy of the data entered.

The relay protection database is, for now, conceived and adapted for storage and maintenance on one PC (most likely the computer of the authorized user), with the possibility of using copies for searching on other computers. Furthermore, it is possible to permit work on the database from other computers in the local network. In this case, the settings of the local network define the computers from which the database can be accessed and the types of permissions (read only or read with the option of updating etc.).

In addition to security at the user level, an additional security measure has been introduced in the form of a password for the database. This password must not be confused with the user password for starting MS Access 2000. Thus, in order to work with the relay protection database, after entering the user's name and password it is also necessary to enter the password of the relay protection database as a second level of security.

## 5 APPLICATION FOR INSPECTING, UPDATING AND PRINTING-OUT DATA

The MS Access 2000 database management system, in addition to various options in the construction of tables and data entry, also offers a series of very powerful tools for searching the database, posing various queries, creating reports and adapting them for hard copies. For the successful use of the database and all the advantages that it offers, a certain amount of knowledge of database technique and the use of the MS Access program is necessary. The MS Access program also offers a series of tools for automating work and rapidly accessing frequently used parts of the base, which due not require familiarity with the individual components and their mutual relationships. Using these tools, a special application has been created to facilitate the searching, updating and printing-out of data from the relay protection database, with the option of activating a series of prepared queries, screen forms and reports. The application also uses other components from the database such as macro instructions and program routines written in the proje omogućiti korisniku što lakše korištenje svih pripremljenih komponenti konkretne baze podataka relejne zaštite uz najmanje truda korisnika i minimum potrebnog znanja o tehnici baza podataka i samom MS Accessu. Korištenjem aplikacije, korisnik ne treba znati puno niti o samom modelu podataka relejne zaštite. Aplikacija je slagana tako da u radu nastoji ponuditi korisniku baš ono što mu određenom trenu može zatrebati. Općenito aplikacija omogućava:

- vođenje korisnika kroz različite opcije, aktiviranje pojedinih komponenti baze i logično kretanje kroz upisane podatke (vertikalno i horizontalno) koristeći niz izbornika,
- korištenje niza ekranskih formi (obrazaca) za lakši pregled, upis i ažuriranje podataka u tablicama s više ugrađenih filtara za pregled i razvrstavanje podataka. Unos podataka putem obrazaca je daleko intuitivniji od direktnog unosa u tablice uz bolji estetski dojam što rad čini ugodnijim i manje zamornim. Uporabom posebno kreiranih dodatnih komandnih tipki u obrascu za npr. trenutačni pregled neke druge tablice, prijelaz na drugi obrazac, pregled različitih uputa za unos itd., rad postaje sigurniji i mnogo brži. Korištenjem složenih obrazaca omogućen je istodobni rad nad više relacijski povezanih tablica (slika 2),
- korištenje pripremljenih parametarskih upita i složenih upita npr. sumarni pregled udešenja zaštite u željenom objektu. Parametarski upiti služe za lociranje specifičnih slogova već kod poziva upita. Složeni višetablični upiti s nizom kriterija uz uporabu matematičkih i logičkih operatora su također vrlo efikasan način pretraživanja baze,
- poziv različitih unificiranih obrazaca za ispis podataka iz baze, npr. izvješće o udešenju zaštite u vodnim poljima nekog objekta, izvješće o udešenju zaštite u nekom polju, sumarno izvješće o udešenju zaštite u odabranom elektroenergetskom objektu (slika 3) itd. Informacije u izvješćima su grupirane na način prikladan za tiskanje na više stranica. Oblik izvješća kreiran je tako da izvješće iz baze izgleda jednako kao dokumentacija koja se do sada koristila za prikaz podataka ugrađenih uređaja relejne zaštite u postrojenjima (slika 4),
- pregled popratne dokumentacije, npr. način označavanja (šifriranja) elemenata nekog polja, opis svake tablice itd. Uz ugrađeni sustav pomoći koji pruža sam program MS Access, npr. ispis opisa svakog polja u dnu monitora pri kretanju kroz tablicu i sl., unutar aplikacije na više mjesta mogu se pozvati posebno kreirani dokumenti s popratnim objašnjenjima. Postoje sljedeći takvi dokumenti:

gramming language Microsoft VBA (Visual Basic for Applications) in order to utilize the power of Access fully. The basic purpose of the application is to enable the user to employ all the prepared components of the actual relay protection database as easily as possible, with the minimum of user effort and the minimum necessary knowledge of database technique and MS Access. When using the application, the user also does not have to know a lot about the relay protection data model. The application is constructed in such a manner that it attempts to offer the user precisely that which he or she would need at a particular moment. Generally, the application makes the following possible:

- guiding the user through various options, activating individual base components and moving logically through the entered data (vertically and horizontally) using a series of menus,
- using a series of screen forms to facilitate the searching, entry and updating of data in the tables with several installed filters for the searching and classification of data. Entry of data via forms is far more intuitive than direct entry into tables and creates a better esthetic impression, so that work becomes more pleasant and less tiring. By using specially created additional command keys in the form for, e.g. the instantaneous view of some other table, switching to another form, reading various instructions, entry etc., operation becomes more secure and much faster. By using complex forms, it is possible to work on several relationally connected tables at the same time (Figure 2),
- using prepared parameter queries and crosstab queries, for example a summary review of the protective settings in a desired object. Parameter queries serve for locating specific records with query calls. Complex multi-relational queries with a series of criteria using mathematical and logical operators are also very effective means for searching the base,
- calling various standardized forms for the printout of data from the base, e.g. reports on protection settings in the transmission line bays of some facility, reports on protection settings in some bay, a summarized report on the protection settings in a selected electrical power facility (Figure 3) etc. Information in the reports is grouped in a manner that is suitable for printing on several pages. The form of the reports is created so that the reports from the database look the same as documents that have been used until now for presenting the data on the installed relay protection equipment in facilities (Figure 4),
- inspection of accompanying documentation, e.g. the manner of coding the elements of a bay, description of each table etc. In addition to the

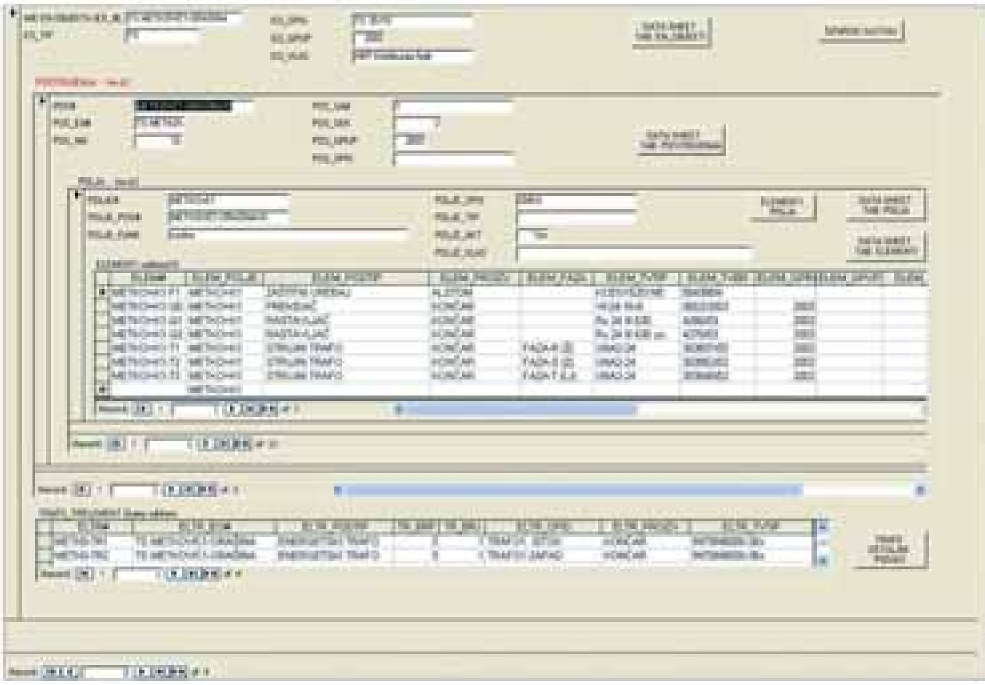
- opis svih relacija u bazi podataka relejne zaštite, s opisom svih atributa iz relacijske sheme te relacijskim vezama među tablicama,
- opis šifarskog sustava koji se koristi pri definiranju i upisu primarnog ključa za svaku relaciju,
- tekstualni opis rada aplikacije za pregled, ažuriranje i ispis podataka s opisom svih izbornika, formi, izvješća itd., odnosno detaljne upute za korištenje ove aplikacije,
- blok dijagram toka aplikacije za pregled, ažuriranje i ispis podataka koji služi za brzo snalaženje unutar hijerarhijske strukture kreiranih izbornika.

Sve opcije koje nudi ova aplikacija mogu se obaviti i bez njenog aktiviranja (ako korisnik ima ovlasti da to obavi), ali tada treba dobro poznavati strukturu podataka i tehnike dizajniranja komponenti baze podataka ili pak nazive ranije kreiranih obrazaca, upita i izvješća koja se pozivaju u aplikaciji. Akcije nad bazom podataka koje nisu predviđene u aplikaciji mogu se obaviti izvan aplikacije. Dizajn aplikacije može mijenjati samo administrator baze dok kreiranje novih izvješća, upita i sl. mogu raditi svi korisnici. Ukoliko se ukaže potreba za novim sadržajima u aplikaciji ili npr. netko od korisnika iz grupe običnih korisnika kreira upit koji se često koristi, administrator baze ga može ukomponirati u aplikaciju.

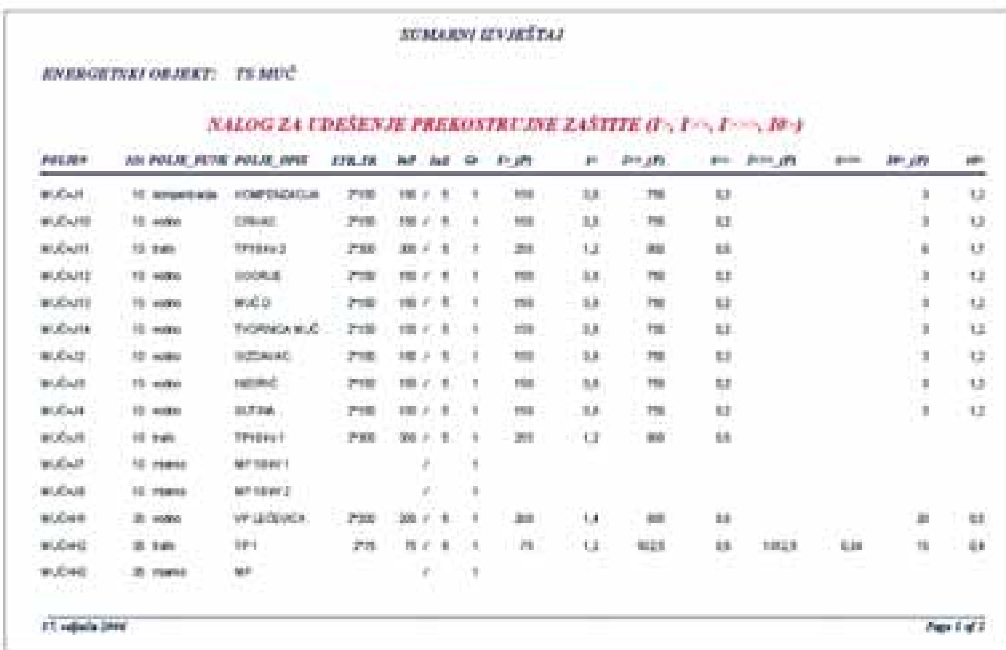
installed help system that the MS Access program provides, e.g. a print-out of a description of each bay on the bottom of the monitor when moving through a table etc., within applications in several places it is possible to call specially created documents with accompanying explanations. There are the following such documents:

- description of all the relationships in the relay protection database, with a description of all the attributes from the relational schema and the relational links among the tables,
- description of the code system that is used in defining and entering the primary key for each table,
- the textual description of the operation of the application for the searching, updating and print-out of data with a description of all the menus, forms, reports etc., i.e. detailed instructions for using these applications,
- a block diagram of the application flow for searching, updating and printing data that provides rapid orientation within the hierarchical structure of the created menus.

All the options offered by this application can also be performed without activating it (if the user has permission to do so), in which case it is necessary to be well acquainted with the structure of the data and the technique of designing database components or the names of previously created forms, queries and reports that are called in the application. Actions on the database that are not anticipated in the application can be performed outside the application. The application design can only be changed by the database administrator although the creation of new reports, queries etc. can be performed by all users. If the need arises for new contents in the application or, for example, one of the users from the group of ordinary users creates a query that is frequently used, the database administrator can incorporate it in the application.



**Slika 2**
Složena ekranska forma
**Figure 2**
Complex screen form




**Slika 3**
Sumarno izvješće o udešenju zaštite u elektroenergetskom objektu TS Muć
**Figure 3**
Summary report on the protection settings in the Muć Substation

**Slika 4**
Izvješće o udešenju zaštite u vodnom polju H1 u transformatorskoj stanici Metković1- Oršina

**Figure 4**
Report on the protection settings at the H1 power line bay in the Metković1- Orašina Substation

| | | | | | |
|---|---|---|---|---|---|
| ENERGETSKI OBJEKT | TS METKOVIĆ1-ORAŠINA | | | OBJEKT OPIS | TS 35/10 |
| POLJE# | METKO=H1 | FUNKCIJA | vodno | POLJE NAZIV | METKOVIĆ2 |

**PPREKIDAČ** KONČAR

| | |
|---|---|
| TVORN. TIP | VK38-16-8 |
| TVORN. BROJ | 0126/2001 |
| IZVEDBA | VAKUUMSKI KOMPAKTNI |
| Un (kV) | 38 |
| Ip (kA) | 16 |
| In (A) | 800 |
| MOTORNI POG. | ✔ |
| U mot | 110 V DC |

**STRUJNI TRANSFORMATOR** KONČAR

| | | | |
|---|---|---|---|
| TVORN. TIP | INA2-38 | | |
| TV.BR. R | 203398/02 | 203397/02 | 203400/02 |
| IZVEDBA | INA | Broj jezgri | 2 |
| In.PRIMARA | 2*200 | SPOJEN (A) | 400 |
| Ith (A) | 2*240 | Idin (A) | 40 |
| Unpm/Uii/Uui (kV) | 36 | 70 | 170 |
| kl.izol. | B | masa (kg) | 30 |
| Ext (%) | 120 | | |

| JEZ | In(A) | Sn(VA) | KL | SV | STEZ1 | STEZ2 |
|---|---|---|---|---|---|---|
| 1 | 5 | 10 | 0,5 | Fs10 | | |
| 2 | 5 | 30 | 10P | 10 | | |

**UPRAVLJAČKI UREĐAJ**

| | |
|---|---|
| TVORN. TIP | |
| TVORN. BRO | |

**ZAŠTITNI RELEJI**

| | F1 | F2 | F3 |
|---|---|---|---|
| PROIZVOĐAČ | ALSTOM | ALSTOM | |
| TVORN. TIP | KCEG14201N51EED | KVTL10001L15AEH | |
| TVORN. BROJ | 584379N | 584324N | |

| ZAŠTITA | GR | UDEŠENJE | | T (S) | KUT | BL | MOD | APU(kbnp-dbnp-st) | APU - opis | DATUM | ISPITAO |
|---|---|---|---|---|---|---|---|---|---|---|---|
| I> | 1 | 3,75 | A | 1,6 | 45 | | | | | | |
| I>> | 1 | 18,75 | A | 0,8 | 45 | | | | | | |
| I>>> | 1 | 15 | A | 0,1 | | | | | | | |
| I0> | 1 | 0,25 | A | 1,1 | 0 | | | | | | |
| I0>>> | 1 | 0,375 | A | 0,4 | | | | | | | |
| I> | 2 | 3,75 | A | 1,6 | | | | | | | |
| I>> | 2 | 18,75 | A | 0,8 | | | | | | | |
| I>>> | 2 | | | | | ✔ | | | | | |
| I0> | 2 | 0,375 | A | 1,1 | | | | | | | |
| I0>>> | 2 | | | | | ✔ | | | | | |

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# 6 TESTIRANJE BAZE PODATAKA I OBUKA KORISNIKA

Prije uvođenja baze podataka relejne zaštite u rad izvršena su temeljita testiranja svih njenih dijelova i obuka korisnika.

Prva testiranja i ocjena performansi rađena su u fazi logičkog modeliranja na relacijskom modelu podataka. Dobar relacijski model s minimalnom logičkom redundancijom podataka osnova je svake dobre baze podataka koja će dugo vremena moći udovoljiti postavljenim zahtjevima. Vrednovanje relacijskog modela radilo se tako što su simulirana pretraživanja i grupiranja podataka na način kako će to vjerojatno raditi budući korisnici baze relejne zaštite. Operacijama relacijske algebre (projekcije, restrikcije, prirodno spajanje itd.) nad definiranim relacijama iz relacijskog modela kreirani su različiti pogledi u podatke (izvedene relacije) radi izdvajanja informacija koje će zanimati korisnike. Također je provjereno da su sve relacijske sheme modela podataka bar u 3. normalnoj formi, kako traži teorija relacijskih modela podataka, čime se izbjegavaju određene anomalije u strukturi baze podataka.

Nakon što je relacijski model podataka zadovoljio postavljene uvjete implementiran je na računalo i ponovno testiran sada kao fizički model. Kako bi provjerili cjelokupan model podataka i njegovo ponašanje u realnim uvjetima uneseni su podaci o elementima relejne zaštite jedne kompletne transformatorske stanice (TS 35/10 kV Muć). Provjereni su odnosi atributa u relacijama, veze među relacijama te formati zapisa pojedinih atributa.

Kad su otklonjeni svi uočeni nedostatci na modelu podataka realizirana je aplikacija za unos, pregled i ažuriranje podataka. Rad kompletne aplikacije provjeren je na način da su podaci elemenata relejne zaštite drugog objekta (TS 35/10 Metković1 – Orašina) uneseni korištenjem aplikacije. Također su na podacima ove dvije transformatorske stanice testirane i dorađene ekranske forme za pregled podataka, različiti upiti te tiskana izvješća iz baze.

U zadnjoj fazi pripreme baze za rad, budući korisnici su najprije upoznati sa svim opcijama, a potom su oni vrednovali mogućnosti baze podataka. Iako je cijeli projekt razvijan u bliskoj suradnji s korisnicima i u ovoj fazi uvaženo je više njihovih sugestija i prijedloga. Kraj procesa testiranja je zaključen unosom podataka o elementima relejne zaštite još jedne transformatorske stanice (TS 35/10 kV Trogir) od strane korisnika.

# 6 DATABASE TESTING AND USER TRAINING

Prior to placing the relay protection database into operation, thorough testing of all its parts was performed and the users were trained.

The first testing and performance evaluations were conducted in the logical modeling phase on the relational data model. A good relational model with minimal logical data redundancy is the basis of every good database that will be able to meet the set requirements over a long period of time. Evaluation of the relational model was performed in such a manner that searches and grouping of data were simulated in the manner that future users of the relay protection database will probably employ. Through operations of relational algebra (projections, restrictions, natural join etc.) on defined relationships from the relational model, various views of the data are created (derived) in order to select information that will interest users. It has also been confirmed that all the relational data models are at least in the third normal form, as required by the theory of relational data models, thereby avoiding certain anomalies in the database structure.

After the relational data model satisfied the established prerequisites, it was implemented on the computer and retested as a physical model. In order to verify the entire data model and its behavior under real conditions, data were entered on elements of the relay protection of a complete substation (Muć 35/10 kV Substation). The connections among the attributes in the relations, the relationships among the relations and the formats of the records of individual attributes were evaluated.

When all the noted shortcomings of the data model were eliminated, the application for entering, searching and updating data was implemented. The operation of the complete application was verified in a manner that the data of the elements of relay protection at a second facility (Metković1 – Orašina 35/10 kV Substation) were entered by using the application. Furthermore, the screen forms for searching data, various queries and printed reports from the database were tested and revised using data from these two substations.

In the final phase of preparing the database for operation, future users were acquainted with all the possibilities in advance. They then evaluated the possibilities of the database. Although the entire project was developed in close collaboration with the users, many of their suggestions and proposals were taken into account in this phase as well. The testing process was concluded with the entry of data on the relay protection elements for one more substation (Trogir 35/10 kV Substation) by the users.

# 7 ZAKLJUČAK

Razvoj i održavanje informacijskog sustava u uvjetima intenzivnog tehnološkog napretka je vrlo opsežan i složen posao. Nužno je imati dugoročnu viziju razvoja koja će biti kompatibilna s postojećim te fleksibilna u prihvaćanju novih tehnologija. Izgradnja informacijskog sustava kroz dijelove koji se mogu samostalno realizirati, a potom povezati u cjelinu jer poštuju sva pravila pri kreiranju modela podataka i izgradnje baze podataka je dobar pristup.

U radu je opisana koncepcija baze podataka zaštitnih uređaja za potrebe odjela relejne zaštite. Prikazan je i opisan razvoj modela podataka zaštitnih uređaja koji poštuje uobičajene standarde i principe izgradnje. Nad modelom podataka razvijena je aplikacija za pregledavanje, izvještavanje i ažuriranje podataka u bazi koja je također opisana. Ovakva baza podataka može funkcionirati kao samostalna cjelina, a također se može integrirati u svoju okolinu. Jasno da se ovakva baza podataka može prilagoditi potrebama konkretnih odjela relejne zaštite dodavanjem novih relacija u relacijskom modelu, dodavanjem novih pregleda i preoblikovanjem izvješća.

# 7 CONCLUSION

The development and maintenance of an information system under conditions of intensive technological advancement is a very extensive and complex task. It is necessary to have a long-term vision of development that will be compatible with existing technologies and flexible in the acceptance of new ones. The construction of the information system using parts that can be independently developed and then combined into a whole is a good approach because all the rules are respected in the creation of the data model and the construction of the database.

The article describes the concept of a protective equipment database for the needs of a relay protection department. A description is also presented of the development of the data model for protective equipment that follows the customary standards and principles of construction. Based upon the data model, an application has been developed for the searching, reporting and updating of data in the base, which is also described. Such a database can function as an independent entity and can also be integrated into its environment. Clearly, such a database can be adapted to the needs of actual relay protection departments by adding new relations in the relational model, adding new views and restructuring reports

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Uredništvo primilo rukopis:
2007-09-30

Prihvaćeno:
2007-10-22

Manuscript received on:
2007-09-30

Accepted on:
2007-10-22

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# DIJAGNOSTIČKI PREGLED RASPADA ELEKTROENERGETSKOG SUSTAVA NA OTOKU RODOSU

# DIAGNOSTIC REVIEW OF A BLACKOUT IN RHODES

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U radu se daje tehnička analiza jednog incidenta koji se dogodio 21. ožujka 2007. godine u 00:50 sati u noći i doveo do dvosatnog potpunog raspada elektroenergetskog sustava na otoku Rodosu. Analiza događanja temelji se na registriranim operativnim podacima kao i nalazima na terenu. Izvršena je tehnička analiza smetnji kako bi se utvrdili vjerojatni uzroci i čimbenici koji su pridonijeli pojavi smetnji. S obzirom da se radi o izoliranom sustavu koji je osobito je osjetljiv na poremećaje, ispitane su uloge zaštite sustava kao i kolebanja proizvodnje vjetroelektrana tijekom incidenta. Izvučeni su zaključci od praktičnog značenja i dane su preporuke korektivnih mjera koje valja provesti kako bi se u budućnosti spriječile takve smetnje.

A technical review of an incident on March 21, 2007 that began at 00:50 a.m. and led to a two-hour blackout of the island of Rhodes electric power system is presented with the complete sequence, including all the relevant registered operational data as well as the on-site field findings. A technical analysis of the disturbance was performed to determine the probable causes and factors that contributed to the duration of the disturbance. Since the system is an isolated one, it is particularly vulnerable to perturbations. The roles of system protection and wind power generation during the incident are examined. Conclusions of practical importance are drawn, including recommendations for corrective measures to be implemented for preventing disturbances of this kind from reoccurring in the future.

Ključne riječi: izolirani elektroenergetski sustav, nestanak struje
Key words: blackout, isolated electric power system

# 1 UVOD

Izolirani otočni elektroenergetski sustavi zanimljivi su s tehničkog stajališta jer pokazuju neke izrazite značajke. Ako je u takvim sustavima prisutan i visok stupanj proizvodnje vjetroelektrana, javlja se u određenim okolnostima veća osjetljivost na pogonske poremećaje.

Elektroenergetski sustav grčkog otoka Rodosa izolirani je sustav s ukupno 234 MW instaliranog kapaciteta termoelektrana (5 dizelskih, 2 parne i 4 plinske turbine) te 15 MW instalirane snage u vjetroelektranama. Međutim, zbog nekih tehničkih problema i karakteristika termoelektrana, stvarna snaga termoelektrana iznosi tek približno 192 MW. Godine 2006. proizvodnja u satu vršnog opterećenja iznosila je 192,6 MWh. To znači da sustav nije uvijek imao na raspolaganju rezervnu snagu.

U ovom se članku istražuje incident poremećaja sustava 21. ožujka 2007. godine koji je započeo u 00:50 sati u noći i doveo do dvosatnog raspada elektroenergetskog sustava na otoku Rodosu.

U vrijeme neposredno prije incidenta u pogonu su bili dva parna bloka (ATM 1 i ATM 2), svaki opterećen s 10 MW (rotirajuća rezerva svakog agregata 2 MW), dva dizelska bloka (D1 i D3): s opterećenjem 6 MW (rotirajuća rezerva 5 MW), ostala proizvodnja s 12 MW (rotirajuća rezerva 5 MW) te 12 MW vjetroelektrana. Vremenski uvjeti bili su loši i jamačno su odigrali određenu ulogu na početku incidenta. Na slici 1 dana je jednopolna shema sustava.

Smetnje u sustavu započele su asimetričnim trofaznim kratkim spojem bez zemljospoja. Taj je kvar uspješno uklonjen. Međutim, zbog nestabilnosti uzrokovane zaštitnim mehanizmima sustav se nije oporavio već je postupno gubio proizvodnju i izazivao značajnu redukciju opterećenja što je, nakon 2 minute i 45 sekundi od uklanjanja prvog kvara, konačno dovelo do potpunog raspada elektroenergetskog sustava.

# 1 INTRODUCTION

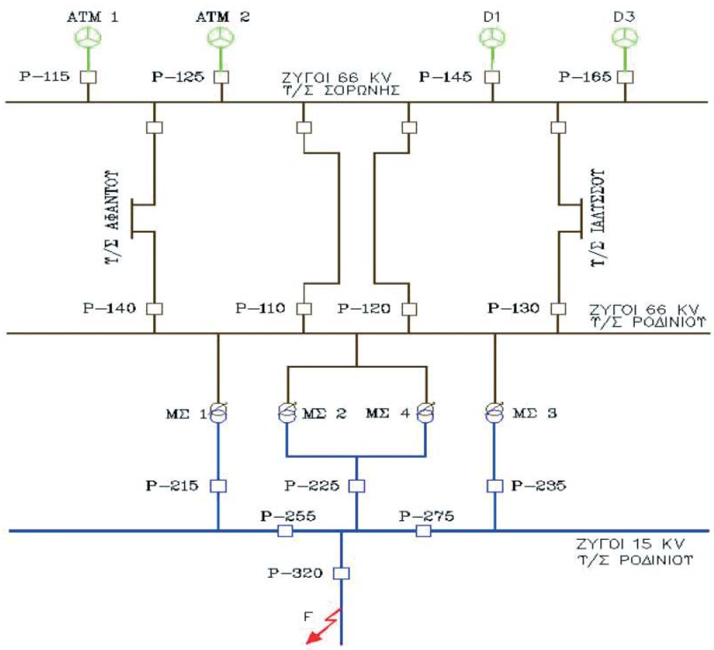
Isolated island power systems are of interest from the technical point of view because they exhibit notable characteristics. For example, when there is a high penetration of wind generation, there is greater vulnerability to operation perturbations under certain conditions.

The electric power system of the Greek island of Rhodes is an isolated system with 234 MW installed capacity of thermal plants (5 diesel, 2 steam and 4 gas turbines) plus 15 MW wind generation. However, due to some technical problems and the characteristics of the thermal generating plant, the actual thermal generation capacity is only about 192 MW. In the year 2006, the mean average hourly generation peaked at 192,6 MWh. This means that the system did not have appreciable reserve power at all times.

This article examines the system disturbance incident of March 21, 2007 that began at 00:50 a.m. and led to a two-hour blackout of the Rhodes Island Electrical Power System.

At the time just before the incident, the system was operating with 2 steam units (ATM 1, and ATM 2) with 10 MW production each (a spinning reserve of 2 MW each) and 2 diesel units (D1, and D3): one producing 6 MW (with a 5 MW spinning reserve) and the other generating 12 MW (with a 5 MW spinning reserve). At the same time, wind generation was 12 MW. A one-line diagram of the system is shown in Figure 1. The weather conditions were severe and played a definite role at the start of the incident.

The system disturbance began with an asymmetrical three-phase fault, not involving ground. This fault was successfully cleared. However, due to instabilities triggered by the protective mechanisms, the system never really recovered, gradually losing generation and causing significant load shedding, which finally led to a complete blackout lasting 2 minutes and 45 seconds after the initial fault had been cleared.




**Slika 1**
Jednopolna shema sustava na početku smetnje
**Figure 1**
One-line diagram of the system at the start of the fault

Kvar se dogodio na trafostanici Rhodini na distribucijskom vodu napajanom putem prekidača P-320 od 15 kV sabirnice, kako je prikazano na slici 1. Nakon gubljenja struje iz voda aktivirana je zaštita i otpušteni su prekidači P-320, P-255 i P-225. Zbog kvara je izgorio drveni stup distribucijskog voda te se kasnije morao zamijeniti. Vrijeme je bilo vrlo loše u trenutku kvara, pri čemu je jak vjetar raspršivao kapljice morske vode po izolatorima vodova, što je intenziviralo površinsko pražnjenje. Naknadnom analizom pronađen je srednji fazni vodič (u vodoravnom rasporedu od 3 faza) prekinut na jednom drvenom stupu. Isto se dogodilo s drugim stupom istog voda gdje su, osim prekinutog srednjeg vodiča, također bili razbijeni porculanski izolatori, najvjerojatnije kao posljedica struje zemljospoja. Taj je početni kvar konačno uklonjen oko 13 sekundi nakon što se dogodio. Međutim, 19 sekundi nakon uklanjanja kvara ispao je parni blok #1 a potom, 2 minute i 45 sekundi nakon uklanjanja kvara, i parni blok #2, što je rezultiralo raspadom elektroenergetskog sustava.

The fault occurred at the Rhodini substation on the distribution line fed through the breaker P-320 from the 15 kV bus, as shown in Figure 1. Following the fault, protection was activated and tripped the breakers P-320, P-255 and P-225. As a result of the fault, a wooden pole of the distribution line burned and had to be replaced later. The weather was severe at the time of the fault, with strong wind spraying sea water droplets over the line insulators, thereby increasing the likelihood of a flashover. Post-mortem examination found the jumper wire for the middle phase conductor (in a horizontal arrangement of the 3 phases) cut at another wooden pole of the same distribution line. The same thing also happened to another pole of the same line where, in addition to a broken middle jumper wire, its porcelain insulators were also broken. This would most likely imply that these were the results of the fault current. This initial fault was finally cleared at about 13 sec after it happened. However, 19 sec after the fault clearance, Steam Unit #1 was lost, and 2 min and 45 sec after the fault clearance Steam Unit #2 was lost, resulting in the blackout.

## 2 ANALIZA INCIDENTA

Kako sustavu SCADA u kontrolnom centru nedostaju neke važne funkcije bilo je moguće tek samo bilježenje pogonskih podataka u realnom vremenu, dok se u mnogim slučajevima događaju značajna zakašnjenja u bilježenju podataka. Iz ispitivanja zabilježenih događaja i podataka moguće je zaključiti kako je smetnja započela asimetričnim trofaznim kratkim spojem bez zemljospoja. Ovaj zaključak temelji se na vremenskim krivuljama izmjenične struje zabilježenih digitalnim relejima prekidača P-225 i P-255 (slika 2), koji su pokazivali nepostojanje struje zemljospoja. Moglo se također zamijetiti da impendancije kvara variraju s vremenom, upućujući na električno iskrenje kao uzrok. Oscilogrami 1 i 2 (slike 3 i 4) prikazuju napone na sabirnicama 66 kV na trafostanici Rhodini, odnosno struje na prekidaču 66 kV P-110 onako kako su se i razvijali. Naknadni vremenski oscilogrami 3 i 4 (slike 5 i 6) tu oscilaciju (frekvencije 100 Hz) jasnije prikazuju. Oscilacija se održava do kraja (kao što je razvidno iz oscilograma 5 (slika 7). To može značiti i da je automatskim regulatorima napona (AVR) potrebno podešavanje.

Iz oscilograma napona moguće je izračunati veličinu napona kao funkciju vremena, i to od nastanka kvara do potpunog pada napona, kako je prikazano na slici 8.

Tijekom smetnje zabilježene su promjene frekvencije širokog raspona. Relevantni podaci prikazani su na slici 9 na kojoj je vidljiva minimalna frekvencija od 47,7 Hz (2 s nakon početka smetnje) i maksimalna frekvencija od 54 Hz (16 s nakon početka smetnje).

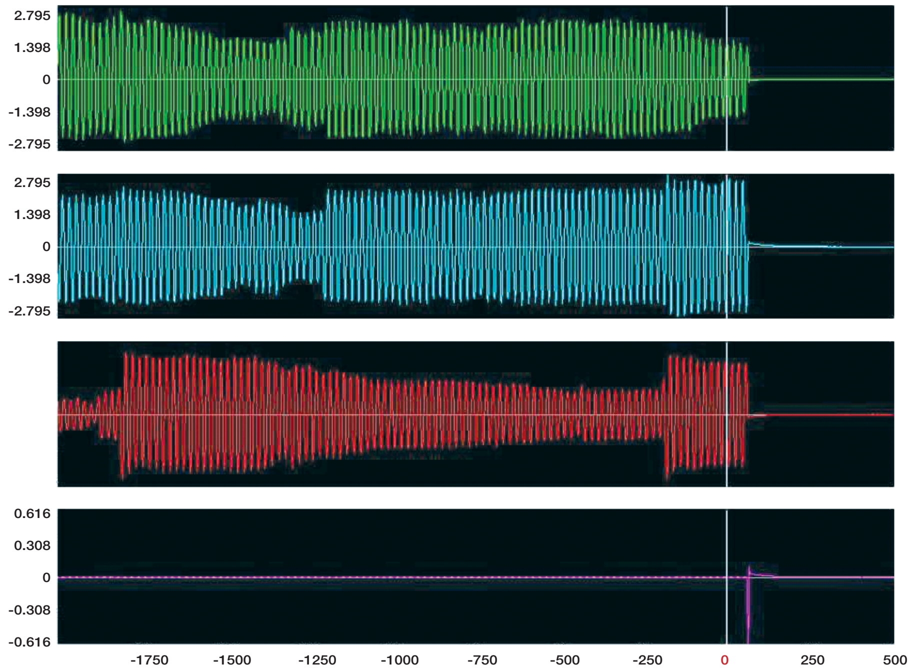
## 2 INCIDENT ANALYSIS

At the outset, one should note that the SCADA at the Control Center leaves important functionalities to be desired. As a result, real-time registration of operation is only partially possible, while in many cases significant time delays occur in data registration. From examination of the registered events and data, one is able to see the following. The fault began as an asymmetrical three-phase fault, not involving the ground. This was evident from the time alternating current curves registered by the digital relays of the P-225 and

P-255 (Figure 2) breakers, which showed zero earth current. It could also be observed that the fault impedances varied randomly with time, suggesting that the electric-arcing of varying spans was the cause. Oscillograms 1 and 2 (Figures 3 and 4) show the voltages at the 66 kV buses at Rhodini and the currents at the 66 kV breaker P-110, respectively. These oscillograms show oscillation developing as time progresses. Subsequent time Oscillograms 3 and 4 (Figures 5 and 6) show this (100 Hz frequency) oscillation more clearly. This oscillation is sustained to the end (as seen in Oscillogram 5 (Figure 7). This could indicate that the automatic voltage regulators (AVR) need adjustments.

From the voltage oscillogram, one can calculate the voltage magnitude as a function of time, from the occurrence of the fault up to the voltage collapse, as shown in Figure 8.

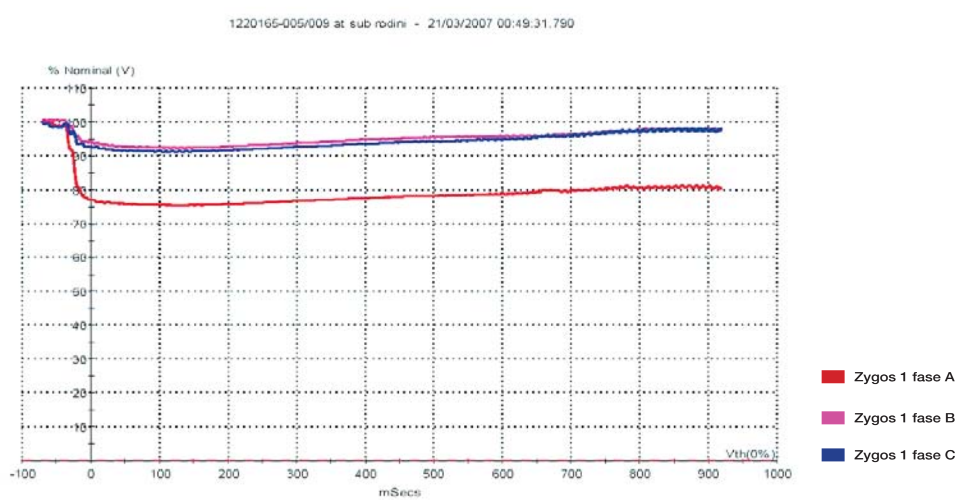
In the course of the disturbance, wide frequency swings were registered. The respective data are shown in Figure 9. In this figure, one can see the minimum frequency of 47,7 Hz (2 s after the start of the disturbance), and the maximum frequency of 54 Hz (16 s after the start of the disturbance).



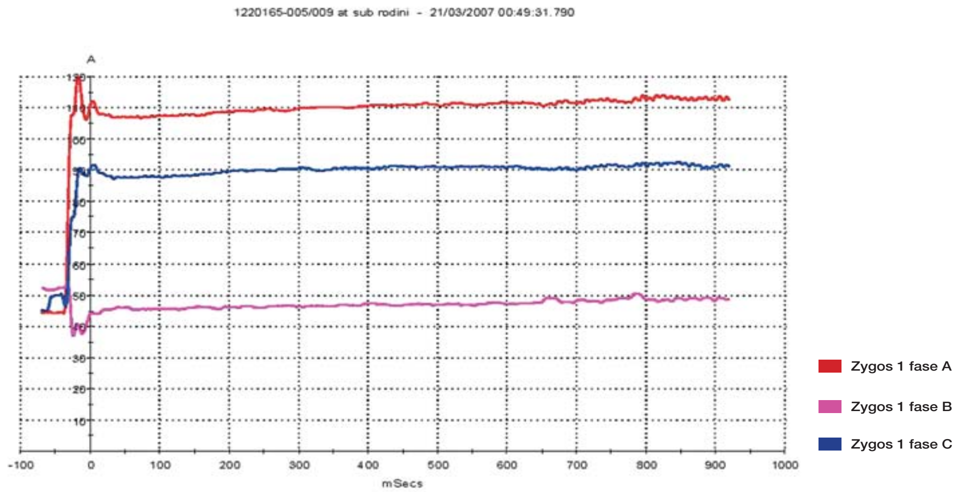

**Slika 2**
Vremenske krivulje izmjeničnih struja faza a, b, c i uzemljenja na prekidaču P-255
**Figure 2**
Time curves of the alternating currents of Phases a, b, c and ground at breaker P-255

Tijekom smetnje tri su se dodatna čimbenika pokazala ključnima. Podešenja podnaponske zaštite za park vjetroelektrana kao i za pojedinačne vjetrogeneratore imala su za posljedicu ispade generatora i gubitak proizvodnje iz vjetroelektrana (24 % ukupne proizvodnje). Podešenja zaštite poduzbudnih limitera dizelskih elektrana imala su za posljedicu njihov ispad. Ispadanje 40 MW opterećenja, zbog rada automatske podfrekvencijske zaštite, rezultiralo je u preostaloj snazi od 10 MW napajanoj iz parnog bloka #2 u zadnjim trenucima neposredno prije potpunog ispada.

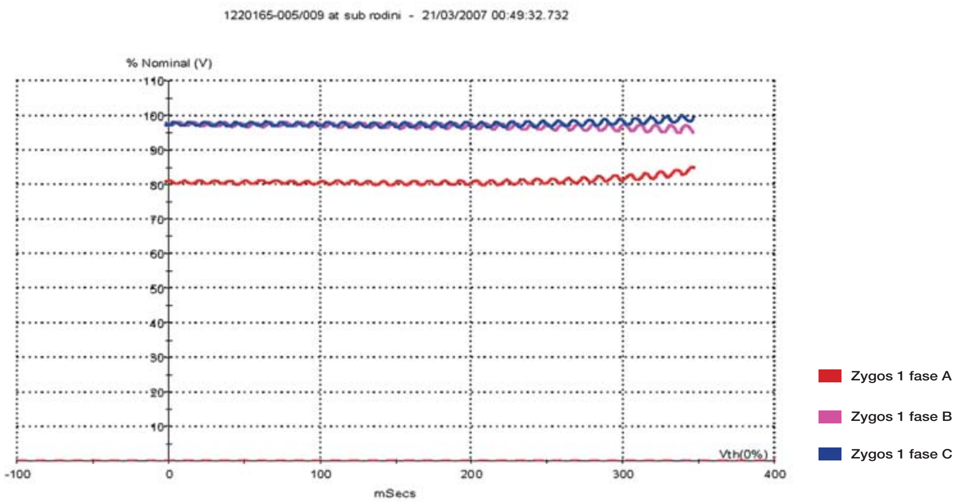
In the course of events, three additional factors were shown to be crucial. The under-voltage protection settings for the wind park and for the individual wind generators resulted in the loss of wind generation (24 % of the total generation). The under-excitation limiters protection settings of the diesel units resulted in the loss of those units. The shedding of 40 MW of load, due to the operation of the automatic under-frequency protection, resulted in a remaining load of 10 MW which was fed from Steam Unit #2 in the final moments just before the collapse.



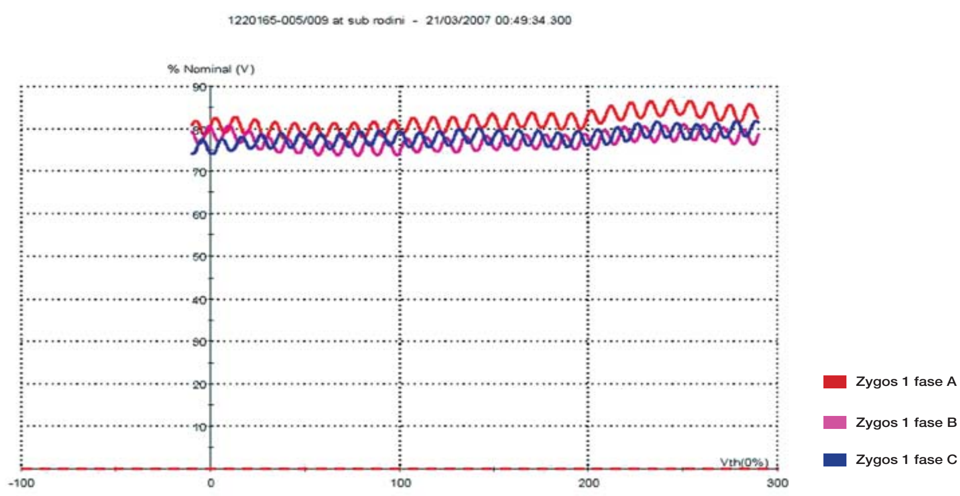

**Slika 3**
Oscilogram 1 – Naponi na sabirnici 66 kV na trafostanici Rhodini (početak gubljenja struje iz voda)
**Figure 3**
Oscillogram 1 – Voltages at the 66 kV bus at Rhodini (the fault begins)



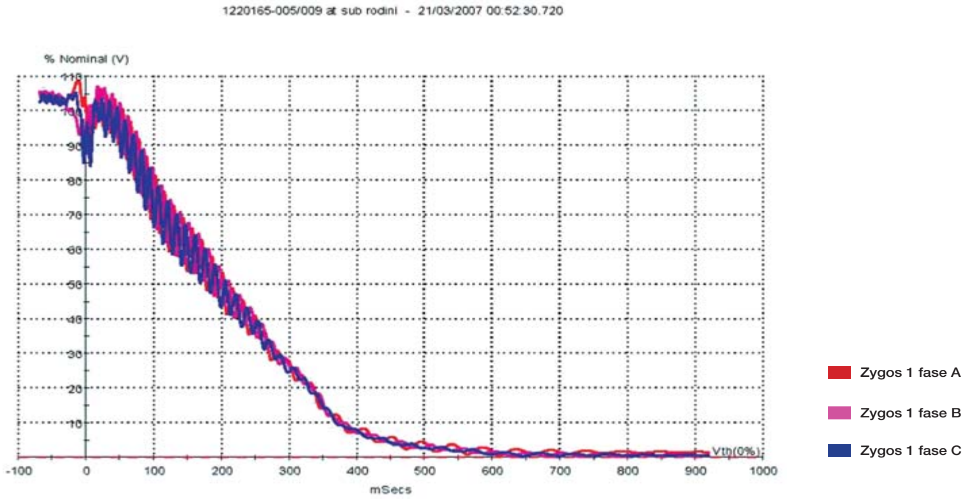

**Slika 4**
Oscilogram 2 – Struje zabilježene na prekidaču 66 kV P-110 na trafostanici Rhodini
**Figure 4**
Oscillogram 2 – Currents registered at 66 kV Breaker P-110 at Rhodini



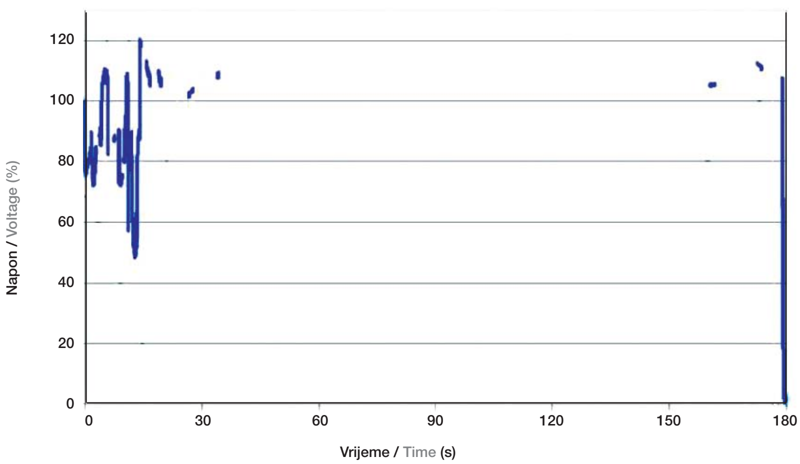

**Slika 5**
Oscilogram 3 – Naponi na sabirnici 66 kV na trafostanici Rhodini
**Figure 5**
Oscillogram 3 – Voltages at 66 kV bus at Rhodini



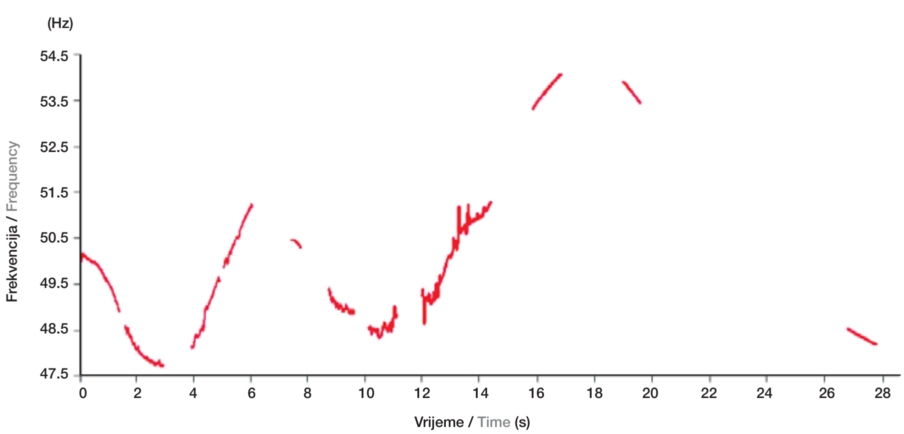

**Slika 6**
Oscilogram 4 – Naponi na sabirnici 66 kV na trafostanici Rhodini
**Figure 6**
Oscillogram 4 – Voltages at 66 kV bus at Rhodini




**Slika 7**
Oscilogram 5 – Napon na sabirnici 66 kV na trafostanici Rhodini (nestanak struje vidljiv na kraju)
**Figure 7**
Oscillogram 5 – Voltage at 66 kV bus at Rhodini (blackout seen at the end)




**Slika 8**
Varijacija napona na sabirnici 66 kV (u %) tijekom smetnje
**Figure 8**
66 kV bus voltage variation (in %) during the disturbance




**Slika 9**
Trend varijacije frekvencije zabilježen tijekom smetnje
**Figure 9**
Frequency variation trend registered during the disturbance

# 3 ZAKLJUČCI

Elektroenergetski sustav otoka Rodosa, kao jedan izoliran sustav, osjetljiv je na smetnje. Distribucijski sustav srednjenaponskih nadzemnih vodova u blizini obale također je osjetljiv na učinke morske soli koja negativno utječe na pouzdanost izolacije.

Osjetljivost proizvodnje vjetroelektrana na kolebanja u naponu mreže kao i ukupna zaštita sustava odigrale su ključnu ulogu u razvijanju poremećaja koji je doveo do raspada elektroenergetskog sustava.

Trenutačno se razmatra nadogradnja prijenosnog sustava na otoku Rodosu sa sadašnjih 66 kV na 150 kV što bi se trebalo realizirati u naredne dvije do tri godine. Osim izgradnje prijenosne mreže, potrebno je nadograditi i sustav SCADA te sustave zaštite.

# 3 CONCLUSIONS

As an isolated system, the Rhodes Island system is vulnerable to disturbances. The MV overhead line distribution system in the vicinity of the coast is also vulnerable to the effects of sea salts that adversely affect the reliability of insulation.

The sensitivity of wind generation to voltage swings as well as the overall system protection played a critical role in the development of the perturbation which led to the blackout.

In view of the fact that the transmission system on Rhodes Island is currently being considered for an upgrade from the present 66 kV to 150 kV, scheduled for the next two-to-three years, it is important that the SCADA system is upgraded as well. The protection scheme should also be upgraded.

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Uredništvo primilo rukopis:
2007-07-25

Prihvaćeno:
2007-09-27

Manuscript received on:
2007-07-25

Accepted on:
2007-09-27

# NUMERIČKI PRORAČUN NISKOFREKVENCIJSKIH ELEKTROMAGNETSKIH PRIJELAZNIH POJAVA U ENERGETSKIM TRANSFORMATORIMA

# THE NUMERICAL CALCULATION OF LOW FREQUENCY ELECTROMAGNETIC TRANSIENT PHENOMENA IN POWER TRANSFORMERS

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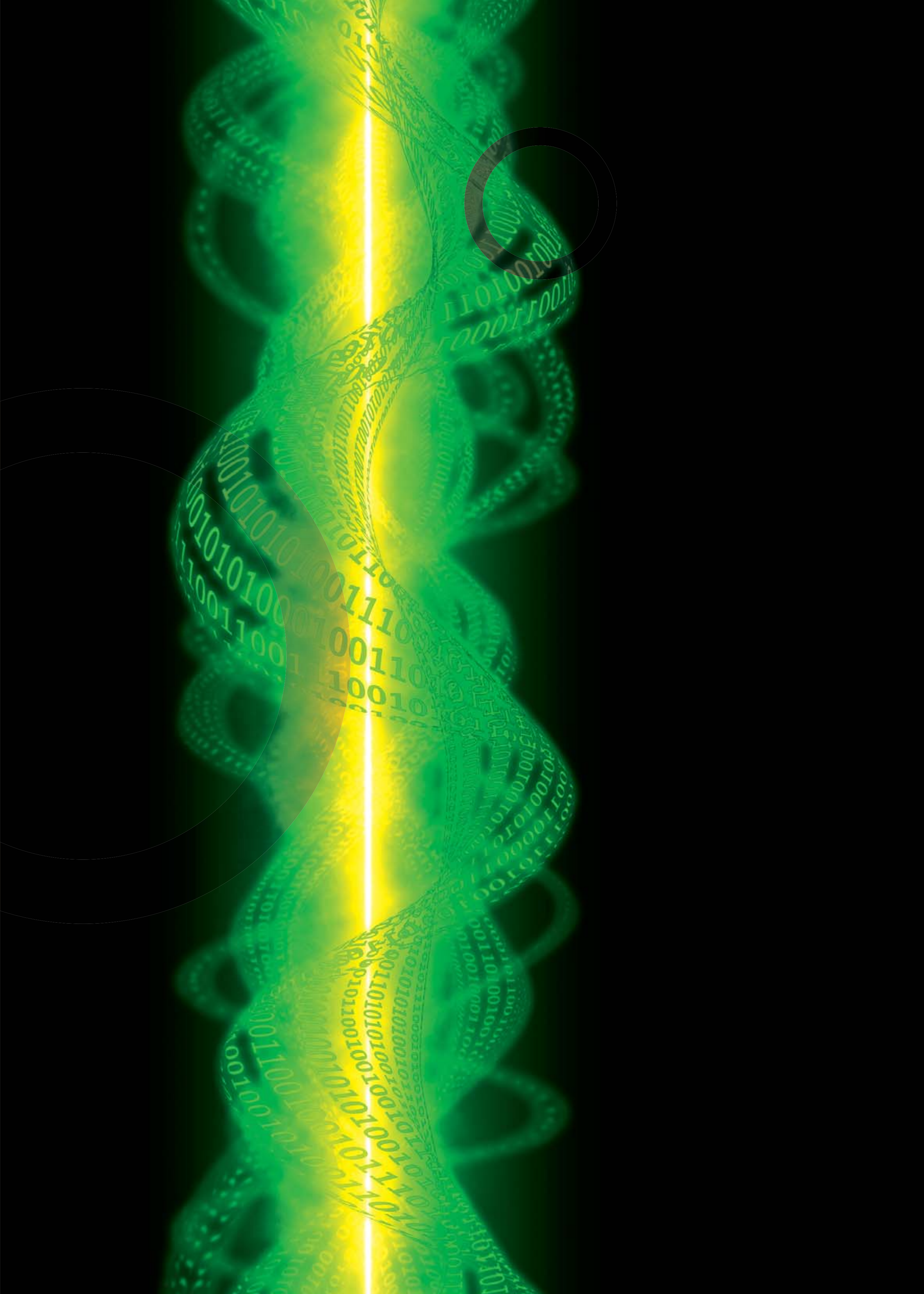
U radu je predstavljen model transformatora primjenjiv u niskofrekvencijskim elektromagnetskim prijelaznim pojavama, frekvencija reda oko 1 kHz. Analiziran je primjer uklapanja neopterećenog energetskog transformatora. Prvo je pokazan pojednostavljeni analitički pristup, a zatim, zbog njegova ograničenja, u analizu je uveden numerički pristup rješavanja krutih diferencijalnih jednadžbi koje opisuju prijelaznu pojavu. U oba slučaja je realiziran algoritam za generiranje valnih oblika varijabli stanja. Rezultati oba algoritma su uspoređeni s rezultatima MATLAB/Simulink/Power System Blockset, namjenskog programa za analizu elektromagnetskih prijelaznih pojava u elektroenergetskom sustavu. Razvijeni algoritam se može uspješno koristiti u ostalim niskofrekvencijskim prijelaznim pojavama gdje je glavni predmet analize nelinearni karakter transformatora: ferorezonancija, ispad tereta, kvarovi kod transformatora itd.

In this article, a transformer model is presented that is applicable to low frequency electromagnetic transient phenomena of up to 1 kHz. An example of the energization of a no-load transformer is analyzed. A simplified analytical approach is presented first. Due to the limitations of this approach, a numerical approach is introduced for the solution of the stiff differential equations that describe the transient phenomena. In both cases, algorithms have been developed for generating the waveforms of the state variables. The results of both algorithms are compared to the results of the MATLAB/Simulink/Power System Blockset for the analysis of electromagnetic transient phenomena in electrical energy systems. Developed algorithm with the introduced numerical approach can be used successfully in other low frequency transient phenomena where the main subject of analysis is the nonlinear character of the transformer: ferroresonance, load switch-off, transformer faults etc.

Ključne riječi: implicitno trapezno pravilo, krivulja magnetiziranja, krute diferencijalne jednadžbe, uklapanje transformatora

Key words: implicit trapezoidal rule, magnetization curve, stiff differential equations, transformer energization



# 1 UVOD

U niskofrekvencijske prijelazne pojave u transformatorima se obično ubrajaju uklapanje neopterećenih transformatora i ferorezonancija. U spomenutim prijelaznim pojavama parametar, koji dominantno utječe na rezultate prijelaznih pojava, je nelinearni induktivitet željezne jezgre transformatora. Kao posljedica nelinearnosti jezgre može doći do jakih strujnih udara prilikom uklapanja neopterećenih transformatora. Osnovne karakteristike struja uklopa transformatora su relativno velika amplituda, koja dostiže ekstremno i do 10 $I_{naz}$ kao i relativno velika duljina trajanja do postizanja stacionarnog stanja [1]. Ovakve struje često mogu uzrokovati nepotrebno djelovanje zaštitnih uređaja budući da mogu dostići vrijednosti struja kratkog spoja transformatora. S tim u vezi, danas su razvijene različite metode za razlikovanje struje uklapanja od struje kratkog spoja transformatora. Najčešće upotrebljavane tehnike razlikovanja su: harmonijska analiza struje (praćenje drugog harmonika struje) [2], energetske metode [3], metode magnetskih karakteristika transformatora [4], te suvremene tehnike koje se baziraju na upotrebi wavelet transformacije i neuronskih mreža [5], suvremenih korelacijskih algoritama [6], itd.

Posljedica struja uklapanja neopterećenih transformatora mogu biti privremeni, niskofrekvencijski, nesinusoidalni prenaponi [7], koji mogu značajno energetski preopteretiti metal-oksidne odvodnike prenapona koji su instalirani uz transformatore [8]. Zagrijavanje odvodnika bitno zavisi od promatrane konfiguracije mreže i od parametara sustava kao i odgovarajućih početnih uvjeta (trenutak uklopa transformatora, remanentni magnetizam transformatora itd.). Amplituda i duljina trajanja ovakvih privremenih napona, a samim time i zagrijavanje odvodnika prenapona, su znatno izraženiji u uvjetima slabih elektroenergetskih sustava.

Dodatno, uklapanje, odnosno isklapanje transformatora u električnim krugovima koje sadrže kapacitivnosti može dovesti do dugotrajnih ferorezonantnih prekostruja, odnosno prenapona. Tipični primjeri nastanka ferorezonancije nastupaju pri serijskoj kompenzaciji [9] ili pri isklapanju naponskih mjernih transformatora [10], te pri neregularnim sklopnim operacijama trofaznih prekidača (prijevremeni uklop/isklop jedne faze u mrežama sa izoliranom neutralnom točkom) [11].

S obzirom na iznesene praktične strane problema pri niskofrekvencijskim prijelaznim pojavama transformatora, potrebno je naročitu pozornost usmjeriti na pravilno modeliranje transformatora, odnosno simuliranje spomenutih pojava.

# 1 INTRODUCTION

Low frequency transient phenomena in transformers usually include the inrush currents of no-load transformers and ferroresonance. In these transients, the parameter with the dominant impact on the results is the nonlinear inductance of the iron core. As a consequence of the nonlinearity of the core, high inrush currents can occur when energizing no-load transformers. The basic characteristics of transformer inrush currents are relatively high amplitude, which in extreme cases can reach up to 10 $I_{rated}$ as well as the relatively long period of time until a steady state is reached [1]. Such currents frequently can cause unnecessary tripping to occur because they can reach the short-circuit current values of the transformers. In connection with this, various methods have been developed today for differentiating between transformer inrush current and short-circuit current. The most frequently used differentiation techniques are as follows: harmonic analysis of the current (second harmonic component) [2], power differential methods [3], methods based on transformer magnetizing characteristics [4], modern techniques that are based on the use of wavelet transform and neural networks [5], modern correlation algorithms [6] etc.

Consequences of no-load transformer inrush currents can be temporary, low frequency and nonsinusoidal overvoltages [7], which can significantly overload the metal oxide surge arresters that are installed next to the transformers [8]. The thermal stress on surge arresters depends significantly on the network configuration and the system parameters as well as the initial conditions (the instant of energization, remnant magnetism etc.). The amplitude and duration of such transient voltages, together with the thermal stress on surge arresters, are significantly more marked under the conditions of weak powersystems.

Additionally, energizing and de-energizing transformers in electrical networks with capacitance can lead to long term overcurrents or overvoltages due to ferroresonance. Typical examples of ferroresonance occur in series compensation [9], when switching off voltage measuring transformers [10] and due to the abnormal switching operations of three-phase switches (the premature energizing/de-energizing of a transformer phase in networks with an isolated neutral point) [11].

Taking into account the above-described practical aspect of the problem with the low frequency transient phenomena of transformers, particular attention should be devoted to the correct modeling of transformers, i.e. the simulation of these phenomena.

Kao što je već spomenuto, osnovna poteškoća u modeliranju energetskih transformatora je nelinearni karakter induktiviteta željezne jezgre transformatora. Ostali parametri transformatora: otpor i rasipni induktiviteti primarnog i sekundarnog namota kao i otpor koji reprezentira gubitke u željezu uzimaju se konstantnim [12]. Osnovna krivulja magnetiziranja transformatora dana je na slici 1a. Ova krivulja se može kvalitativno aproksimirati s dva pravca, slika 1b, koji predstavljaju tangente u nezasićenom i zasićenom području. Krivulja magnetiziranja energetskih transformatora ima jako oštar prijelaz iz nezasićenog u zasićeno područje. Ovo je posljedica konstruktivne izvedbe visokonaponskih energetskih transformatora. Naime, s porastom naponske razine, odnosno nazivne snage transformatora struja praznog hoda se smanjuje i iznosi [13] oko 5 % do10 % nazivne struje transformatora za transformatore snaga reda 100 kVA i opada sve do vrijednosti oko 0,47 % do 0,59 % nazivne struje transformatora za transformatore snage reda 500 MVA.

Pregled standardnih vrijednosti struje magnetiziranja za energetske transformatore različitih nazivnih snaga dan je tablicom 1. Struja prijelaza u zasićeno područje $i_z$ jednaka je nazivnoj struji pomnoženoj s faktorom ulaska u zasićenje $k$: $i_z = k \cdot i_{0naz}$, gdje je za energetske transformatore obično $1{,}05 \leq k \leq 1{,}3$. Dakle, koljeno krivulje magnetiziranja za energetske transformatore velikih snaga je razmješteno u veoma uskom području nazivne struje transformatora (reda 0,5 % do 1 % $i_{naz}$). Površina, koja je omeđena realnom krivuljom magnetiziranja i njenom aproksimacijom preko dva pravca, ovdje je reda svega oko 0,001 % ako uzmemo da je 100 % površina ispod cijele krivulje magnetiziranja u p.u. sistemu. Logična je posljedica ovako malih nazivnih struja praznog hoda da predstavljanje krivulje magnetiziranja preko svega dva pravca čini gotovo zanemarive pogreške u usporedbi s realnim predstavljanjem krivulje [14].

As previously mentioned, the basic difficulty in modeling power transformers is the nonlinear character of the inductance of the iron transformer core. The other transformer parameters, the resistance and leakage inductance of the primary and secondary windings as well as the resistance that represents losses in iron are assumed to be constant [12]. The basic transformer magnetizing curve is presented in Figure 1a. This curve can be qualitatively approximated with two straight lines, Figure 1b, that represent tangents in the unsaturated and saturated regions. The power transformer magnetizing curve has a very sharp transition from the unsaturated to the saturated regions. This is a consequence of the design of high voltage power transformers. With an increase in the voltage level or rated power of the transformer, no-load current is decreased and amounts to approximately 5 % to 10 % of the transformer rated current [13] for transformers with power ratings of 100 kVA and decreases to a value of approximately 0,47 % to 0,59 % of transformer rated current for transformers with power ratings of 500 MVA.

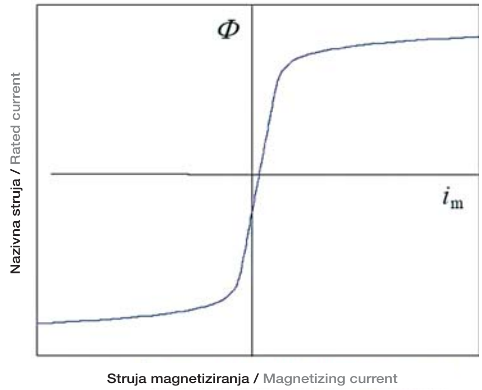
A review of the standard values of power transformer magnetizing currents for various rated powers is presented in Table 1. The transition current to the saturated region $i_z$ is equal to the rated current multiplied by the saturation factor $k$: $i_z = k \cdot i_{0rated}$, where usually for power transformers $1{,}05 \leq k \leq 1{,}3$. Thus, the bend in the magnetizing curve for a high power transformer is in a very narrow region of the transformer rated current (an order of 0,5 % to 1 % $i_{rated}$). The surface, which is bounded by the real magnetizing curve and its approximation by two straight lines is of an order here of only approximately 0,001 % if it is taken into account that 100 % of the surface below the magnetizing curve is in a p.u. system. A logical consequence of such low rated no-load currents is that it is possible to approximate the magnetizing curve using two straight lines with nearly negligible error in comparison to the real curve [14].

Tablica 1 –Tipične vrijednosti struje praznog hoda kao postotak nazivne struje za energetske transformatore
Table 1 –Typical values of no-load current as a percentage of rated current for power transformers

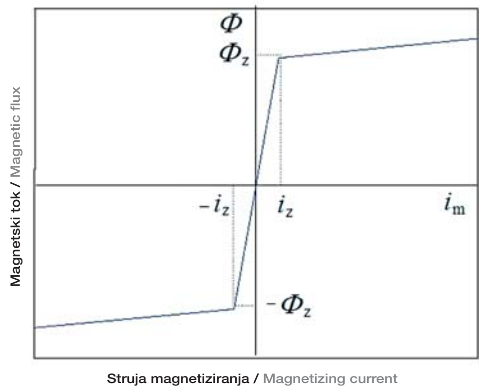
| | | | | | | |
|---|---|---|---|---|---|---|
| $S_{TR}$ (MVA) | 0,1 | 1,0 | 10 | 20 | 40 | 60 |
| $i_0$ (% $i_{naz/rated}$) | 5,0 – 8,0 | 1,75 – 2,32 | 0,35 – 1,1 | 0,8 – 1,2 | 0,65 – 0,94 | 0,58 – 0,84 |
| $S_{TR}$ (MVA) | 80 | 100 | 150 | 200 | 300 | 500 |
| $i_0$ (% $i_{naz/rated}$) | 0,54 – 0,77 | 0,51 – 0,73 | 0,47 – 0,67 | 0,51 – 0,64 | 0,49 – 0,61 | 0,47 – 0,59 |

**Slika 1**
Krivulja magnetiziranja transformatora a) i njena aproksimacija preko dva pravca b)
**Figure 1**
Magnetizing curve of transformer a) and its approximation via two straight lines b)

a)

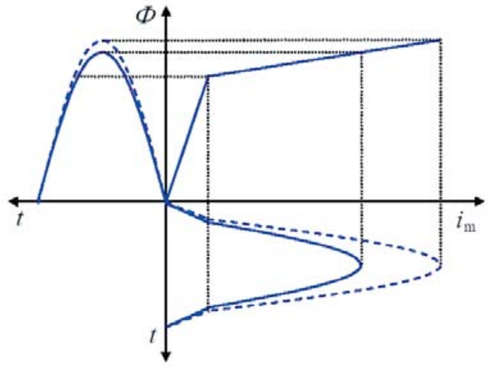



b)

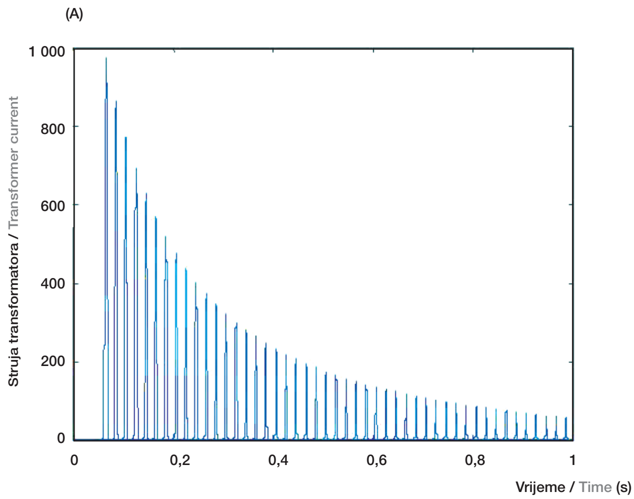



Posljedica nelinearnog karaktera željezne jezgre transformatora je nesinusoidalna struja magnetiziranja transformatora pri sinusoidalnom naponu napajanja, tj. sinusoidalnom magnetskom toku, što je jasno ilustrirano na slici 2. Na istoj slici su prikazana dva oblika struje magnetiziranja za dvije različite tjemene vrijednosti magnetskog toka. Tijekom prijelazne pojave uklapanja transformatora kada magnetski tok može poprimi vrijednosti i veće od svoje dvostruke nazivne vrijednosti [15], dolazi do jakih strujnih udara transformatora, što je pokazano na slici 3.

A consequence of the nonlinear character of the iron transformer core is the nonsinusoidal transformer magnetizing current at the sinusoidal supply voltage, i.e. sinusoidal magnetic flux, which is clearly illustrated in Figure 2. In the same figure, two forms of magnetizing current are presented for two different peak values of the magnetic flux. During the transient phenomena of transformer energization, when the magnetic flux can acquire values greater than twice its rated value [15], high inrush current occurs, as presented in Figure 3.




**Slika 2**
Nesinusoidalna struja magnetiziranja transformatora
**Figure 2**
Nonsinusoidal transformer magnetizing current




**Slika 3**
Tipičan valni oblik struje uklapanja transformatora
**Figure 3**
Typical waveform of transformer inrush current

## 2 MATEMATIČKI MODEL PRI UKLAPANJU NEOPTEREĆENOG ENERGETSKOG TRANSFORMATORA

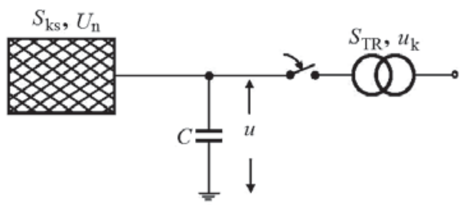
U ovom poglavlju će se analizirati matematički model pri uklapanju neopterećenog energetskog transformatora, slika 4a i b. Između transformatora i točke priključka na mrežu postoji kapacitet $C$, kojim se ekvivalentira prilaz kabelskim ili nadzemnim vodom, kapacitet kondenzatorskih baterija i sl.

## 2 MATHEMATICAL MODEL OF THE ENERGIZATION OF A NO-LOAD POWER TRANSFORMER

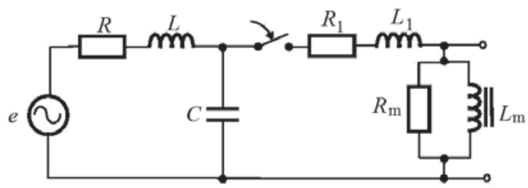
This chapter presents an analysis of a mathematical model of the energization of a no-load power transformer, Figures 4a and b. Between the transformer and the connection point to the network, there is a capacity $C$, which is equivalent to the capacity of a cable or overhead approach line, the capacitance of the capacitors etc.

**Slika 4** Uklapanje neopterećenog energetskog transformatora

Figure 4 The energization of a no-load power transformer




a) Shema uklapanja transformatora na mrežu / Simplified electrical circuit of transformer energization




b) Odgovarajuća zamjenska shema slike a) / Equivalent electrical circuit of Figure a)

Parametri mreže se dobivaju iz podataka o snazi tropolnog kratkog spoja u točki priključka:

The network parameters are obtained from data on the three-phase short-circuit power at the point of connection:

$$L = \frac{U_n^2}{S_{ks} \cdot \omega} \quad . \tag{1}$$

Pretpostavlja se da je odnos $X / R$ za danu mrežu poznat, na osnovi kojega se određuje otpor $R$.

Na osnovi poznate nazivne snage transformatora $S_{TR}$, te napona kratkog spoja moguće je odrediti rasipni induktivitet tansformatora:

It is assumed that the ratio of $X / R$ for the given network is known, on the basis of which we determine resistance $R$.

On the basis of the known transformer rated power $S_{TR}$ and the short-circuit voltage, it is possible to determine the leakage inductance of the transformer:

$$L_1 = \frac{U_n^2}{S_{TR} \cdot \omega} \cdot u_k \, . \tag{2}$$

Ostali podaci, djelatni otpor primarnog namota transformatora $R_1$, djelatni otpor izazvan gubicima u željezu $R_m$, te nelinearni induktivitet željezne

Other data, the effective resistance of the primary transformer winding $R_1$, the effective resistance due to iron core losses $R_m$, and the nonlinear inductance

jezgre transformatora $L_m$, inače definirana krivuljom magnetiziranja $\Phi$-$i_m$ ($\Phi$ je glavni ulančeni magnetski tok, $i_m$ je struja magnetiziranja transformatora), lako se mogu odrediti mjerenjem ili su već dani od strane proizvođača. Ovaj nelinearni induktivitet aproksimiran je s dva pravca u $\Phi$-$i_m$ koordinatnom sustavu, slika 2, što je za energetske transformatore u praksi uglavnom prihvatljivo. Točka ($i_z$, $\Phi_z$) predstavlja kritičnu točku pri prelasku iz nezasićenog u zasićeno područje željezne jezgre. Koeficijenti pravaca ustvari predstavljaju induktivitete u nezasićenom ($L_{m1}$, $\mathrm{const}_1$) i zasićenom području ($L_{m2}$, $\mathrm{const}_2$). Na ovaj način dobivamo funkcionalnu ovisnost struje magnetiziranja o magnetskom toku kao (funkcijom *sign* osiguravamo pozicioniranje u odgovarajućem kvadrantu):

of the transformer iron core $L_m$, otherwise defined by the magnetizing curve $\Phi$-$i_m$ ($\Phi$ is the main linkage magnetic flux, $i_m$ is the transformer magnetizing current), can easily be determined through measurement or are already provided by the manufacturer. This nonlinear inductance is approximated with two straight lines in the $\Phi$-$i_m$ coordinate system, Figure 2, which is generally acceptable in practice for power transformers. Point ($i_z$, $\Phi_z$) represents the critical point at the transition from the unsaturated region to the saturated region of the iron core. The straight lines coefficients actually represent inductances in the unsaturated region $L_{m1}$, $\mathrm{const}_1$ and saturated region $L_{m2}$, $\mathrm{const}_2$. In this manner, we obtain the functional dependence of the magnetizing current on the magnetic flux (we define the position in the corresponding quadrant with the *sign* function) as follows:

$$i_m = \frac{1}{L_{m1}} \Phi , \ |\Phi| \le \Phi_z , \tag{3}$$

$$i_m = \frac{1}{L_{m2}} \Phi + \mathrm{sign}(\Phi) \left( \frac{1}{L_{m1}} - \frac{1}{L_{m2}} \right) \Phi_z , \ |\Phi| > \Phi_z . \tag{4}$$

## 3 ANALITIČKI PRISTUP

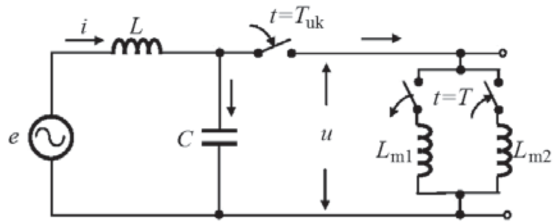
Radi jednostavnosti zanemarit će se sve aktivne elemente sa slike 4b. Dakle, pri prijelaznoj pojavi uklapanja transformatora ako trenutačna vrijednost magnetskog toka, po apsolutnoj vrijednosti premaši kritičnu vrijednost $\Phi_z$, induktivnost transformatora se mijenja sa $L_{m1}$ na $L_{m2}$. To ustvari znači da se trenutak kada magnetski tok dostigne vrijednost $\Phi_z$ može uzeti kao vrijeme $t=T>T_{uk}$ isklapanja induktiviteta $L_{m1}$ odnosno uklapanja induktiviteta $L_{m2}$. Ekvivalentna shema bi u tom slučaju izgledala kao na slici 5. Slično, pri smanjenju magnetskog toka ispod vrijednosti $\Phi_z$ isključuje se induktivitet $L_{m2}$ i uključuje induktivitet $L_{m1}$.

## 3 ANALYTICAL APPROACH

For the purpose of simplicity we shall ignore all the active elements from Figure 4b. In the transient phenomena during transformer energization, if the instantaneous value of the magnetic flux in terms of absolute value exceeds the critical value of $\Phi_z$, the transformer inductance changes from $L_{m1}$ to $L_{m2}$. This actually means that the moment when the magnetic flux reaches the value of $\Phi_z$ can be taken as the time $t=T>T_{uk}$ of switching off the inductance $L_{m1}$, respectively the time of switching on the inductance $L_{m2}$. In this case, an equivalent diagram would look like the one presented in Figure 5. Similarly, when the magnetic flux is decreased below the value of $\Phi_z$, inductance $L_{m2}$ is switched off and inductance $L_{m1}$ is switched on.

**Slika 5**
Uklapanje transformatora – pojednostavljeni model

**Figure 5**
Transformer energization – simplified model




Dakle, promjena trenutačne vrijednosti magnetskog toka pri prelaznoj pojavi uvjetuje prelaske s jednog na drugi pravac što u diferencijalnim jednadžbama koje opisuju ponašanje električnih krugova ustvari znači promjenu koeficijenata. Proces počinje s induktivitetom $L_{m1}$. Uz oznake kao na slici 5 dobiju se diferencijalne jednadžbe koje opisuju ponašanje električnog kruga u proizvoljnom trenutku $t \geqslant T_{uk}$, gdje je $t=T_{uk}$ trenutak uklapanja prekidača :

Therefore, in transient phenomena transition from one straight line to another is conditional upon change in the instantaneous value of the magnetic flux, which in differential equations that describe the behavior of electric circuits actually signifies coefficient changes. The process begins with the inductance $L_{m1}$. Using the same symbols as in Figure 5, differential equations are obtained that describe the behavior of the electric circuit at the arbitrary moment $t \geqslant T_{uk}$ , where $t=T_{uk}$ is the moment that the switch is turned on:

$$E_m \cos \omega t = \frac{d^3 \Phi}{dt^3} + \frac{1}{C}\left(\frac{1}{L_{m1}} + \frac{1}{L}\right)\frac{d\Phi}{dt}, \ |\Phi| \le \Phi_z, \tag{5}$$

$$E_m \cos \omega t = \frac{d^3 \Phi}{dt^3} + \frac{1}{C}\left(\frac{1}{L_{m2}} + \frac{1}{L}\right)\frac{d\Phi}{dt}, \ |\Phi| > \Phi_z. \tag{6}$$

Rješava se prvo diferencijalna jednadžba (5). Uz izraz za prirodnu kružnu frekvenciju kruga:

Differential equation (5) is solved first. When the natural circular frequency of the circuit is as follows:

$$\omega_{01} = \sqrt{\frac{1}{C}\left(\frac{1}{L_{m1}} + \frac{1}{L}\right)}, \tag{7}$$

dobiva se opće rješenje diferencijalne jednadžbe (5):

the general solution to equation (5) is obtained:

$$\Phi(t) = a + b\cos \omega_{01} t + c \sin \omega_{01} t + B \sin \omega t\,. \tag{8}$$

Konstante $a$, $b$ i $c$ određuju se iz početnih uvjeta:

Constants $a$, $b$ and $c$ are determined from the initial conditions:

$$\Phi(T_{\text{uk}}) = \Phi_0 \,, \tag{9}$$

$$u(T_{\text{uk}}) = \left.\frac{\mathrm{d}\Phi}{\mathrm{d}t}\right|_{t=T_{\text{uk}}} = U_0 \,, \tag{10}$$

$$i_{\mathrm{C}}(T_{\text{uk}}) = C\left.\frac{\mathrm{d}u}{\mathrm{d}t}\right|_{t=T_{\text{uk}}} = C\left.\frac{\mathrm{d}^2\Phi}{\mathrm{d}t^2}\right|_{t=T_{\text{uk}}} = I_{\mathrm{C}0} \,. \tag{11}$$

Napon $U_0$ i struja $I_{C0}$ se određuju iz stanja prije uklapanja prekidača:

Voltage $U_0$ and current $I_{C0}$ are determined from the state prior to turning on the switch:

$$U_0 = \frac{E_{\mathrm{m}}}{1-\omega^2 LC}\cos\omega T_{\text{uk}} \,, \tag{12}$$

$$I_{\mathrm{C}0} = -\frac{\omega C E_{\mathrm{m}}}{1-\omega^2 LC}\sin\omega T_{\text{uk}} \,. \tag{13}$$

Koeficijenti $a$, $b$ i $c$ se dobivaju iz matrične jednadžbe koja se formira na osnovi jednadžbi (9) do (13):

Coefficients $a$, $b$ and $c$ are obtained from the matrix equation formed on the basis of equations (9) to (13):

$$\boldsymbol{M} = \boldsymbol{K}^{-1}\cdot\boldsymbol{N}, \tag{14}$$

gdje su matrice $\boldsymbol{M}, \boldsymbol{K}$ i $\boldsymbol{N}$ redom:

where matrices $\boldsymbol{M}$, $\boldsymbol{K}$ and $\boldsymbol{N}$ are as follows:

$$\boldsymbol{M} = \begin{bmatrix} a \\ b \\ c \end{bmatrix}, \tag{14a}$$

$$\boldsymbol{K} = \begin{bmatrix} 1 & \cos\omega_{01}T_{\text{uk}} & \sin\omega_{01}T_{\text{uk}} \\ 0 & -\omega_{01}\sin\omega_{01}T_{\text{uk}} & \omega_{01}\cos\omega_{01}T_{\text{uk}} \\ 0 & -\omega_{01}^2\cos\omega_{01}T_{\text{uk}} & -\omega_{01}^2\sin\omega_{01}T_{\text{uk}} \end{bmatrix}, \tag{14b}$$

$$\boldsymbol{N} = \begin{bmatrix} \Phi_0 - B\sin\omega T_{\text{uk}} \\ U_0 - B\omega\cos\omega T_{\text{uk}} \\ I_0/C + B\omega^2\sin\omega T_{\text{uk}} \end{bmatrix}. \tag{14c}$$

Kada se odrede konstante $a$, $b$ i $c$ tada se za vremenski oblik magnetskog toka $\Phi(t)$, napona $u(t)$ na transformatoru i struje kondenzatora $i_C(t)$ dobiva:

When constants $a$, $b$ and $c$ are determined, the magnetic flux $\Phi(t)$, transformer voltage $u(t)$ and condenser current $i_C(t)$ waveforms as a function of time are then as follows:

$$\Phi(t) = a + b\cos\omega_{01}t + c\sin\omega_{01}t + B\sin\omega t\,, \tag{15}$$

$$u(t) = -b\omega_{01}\sin\omega_{01}t + c\omega_{01}\cos\omega_{01}t + B\omega\cos\omega t\,, \tag{16}$$

$$i_C(t) = C\left(-b\omega_{01}^2\cos\omega_{01}t - c\omega_{01}^2\sin\omega_{01}t - B\omega^2\sin\omega t\right). \tag{17}$$

U jednadžbi (8) konstanta $a$ predstavlja istosmjernu komponentu magnetskog toka, $b$, $c$ i $\omega_{01}$ konstante kojima je definiran vlastiti odziv, a $B$ i $\omega$ konstante kojima je definiran prinudni odziv u rješenju za magnetski tok. Posljednje tri jednadžbe vrijede sve dok je zadovoljeno $|\Phi| \leq \Phi_z$. U protivnom, kada bude $|\Phi| > \Phi_z$ tada ponašanje električnog kruga opisuje diferencijalna jednadžba (6) opisuje stanje ravnoteže s parametrom $L_{m2}$ umjesto $L_{m1}$. Početni uvjeti za novu diferencijalnu jednadžbu (6) su posljednje trenutačne vrijednosti rješenja prvobitne jednadžbe (5). Rješenja diferencijalne jednadžbe (6) se dobivaju istim postupkom kao rješenja jednadžbe (5). Analogno se razmišlja pri ponovnom smanjenju magnetskog toka ispod vrijednosti $\Phi_z$ sa odgovarajućim početnim uvjetima koji su određeni posljednjim trenutačnim vrijednostima stare diferencijalne jednadžbe.

Struja magnetiziranja transformatora $i_m$ određuje se na osnovi relacija (3) i (4).

Generalno se može organizirati algoritam koji bi prateći vrijednost trenutačnog magnetskog toka rješavao diferencijalne jednadžbe (5) i (6) s odgovarajućim početnim uvjetima. Uvodeći težinske koeficijente $k_1$ i $k_2$ koji bi uzimali vrijednosti 0 ili 1 moguće je načiniti petlju koja bi stalno računala vrijednost magnetskog toka u zasićenom ili nezasićenom području vodeći računa o odgovarajućim početnim uvjetima.

Remanentni magnetizam transformatora $\Phi_{rem}$ moguće je uvažiti ako se u proračun krene s tom vrijednošću, $\Phi(T_{uk}) = \Phi_{rem}$. Histerezna petlja je zanemarena, što je u praktičkim primjerima za energetske transformatore sasvim prihvatljivo [16].

In equation (8), constant $a$ represents the DC component of the magnetic flux, $b$, $c$ and $\omega_{01}$ are the constants by which the self response is defined, and $B$ and $\omega$ are the constants by which the forced response is defined in the solution for the magnetic flux. The last three equations are valid until the condition of $|\Phi| \leq \Phi_z$ is met. Otherwise, when $|\Phi| > \Phi_z$, differential equation (6) describes the behavior of the electric circuit with the parameter $L_{m2}$ instead of $L_{m1}$. The initial conditions for a new differential equation (6) are the last instantaneous values from the solution of equation (5). The solution to differential equation (6) is obtained according to the same procedure as the solution to equation (5). An analogous procedure is used when the magnetic flux is again reduced below the value of $\Phi_z$ with the corresponding initial conditions that are determined using the instantaneous values of the previous differential equation.

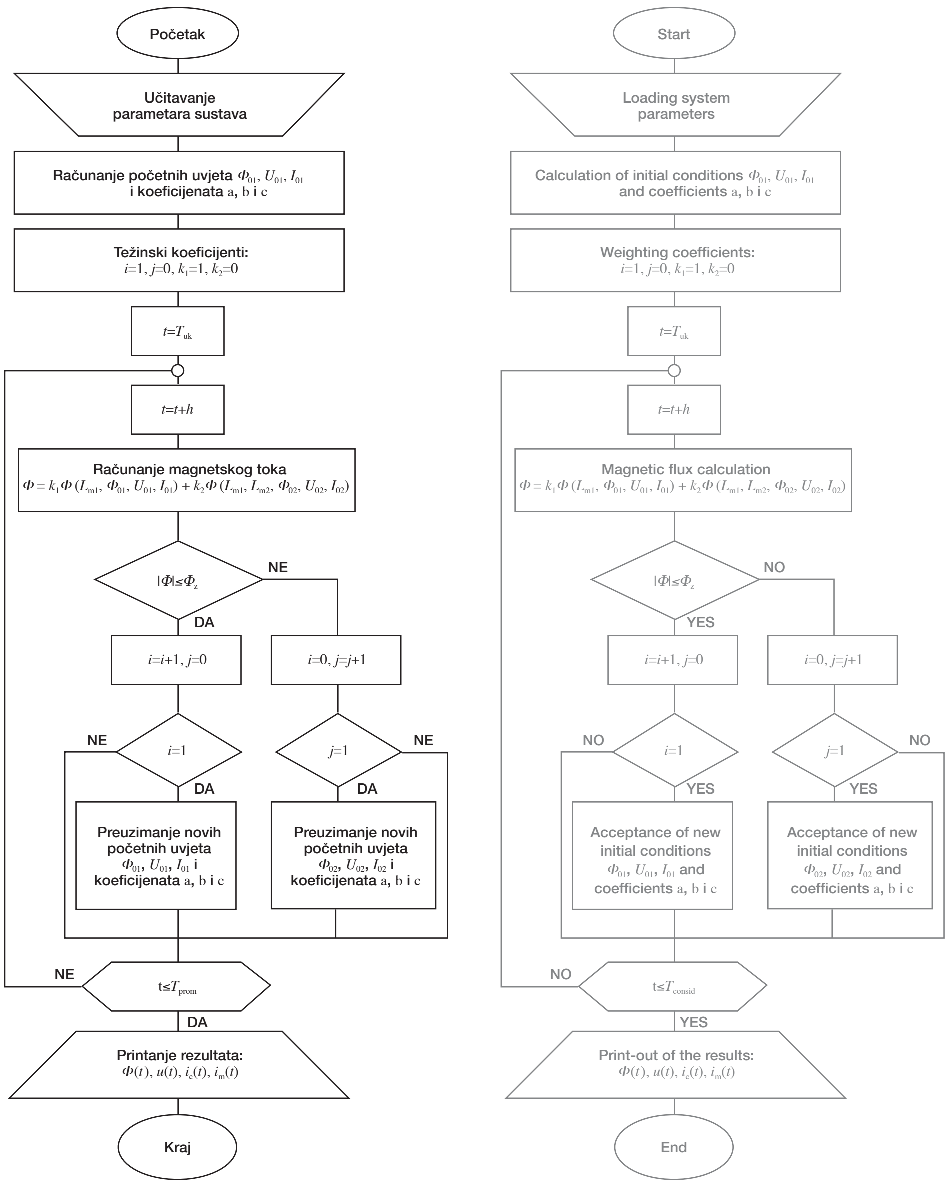
The transformer magnetizing current $i_m$ is determined on the basis of equations (3) and (4).

It is generally possible to develop an algorithm that would solve differential equations (5) and (6) by following the value of the instantaneous magnetic flux with the corresponding initial conditions. By introducing weighting coefficients $k_1$ and $k_2$ that would assume the value of 0 or 1, it is possible to make a loop that that would constantly calculate the value of the magnetic flux in the saturated and unsaturated regions, taking the corresponding initial conditions into account.

Transformer remnant magnetism, $\Phi_{rem}$ can be taken into account if this value is entered into the calculation $\Phi(T_{uk}) = \Phi_{rem}$. The hysteresis loop is ignored, which is completely acceptable in practical applications for power transformers [16].

Pojednostavljeni algoritam računanja varijabli stanja (magnetskog toka, napona i struje) dan je na slici 6. Otežavajuća činjenica pri realizaciji programa je da se početni uvjeti pri svakom prijelazu iz jednog u drugo područje stalno moraju preračunavati.

A simplified algorithm for the calculation of state variables (magnetic flux, voltage and current) is presented in Figure 6. A complicating factor in the implementation of the program is that the initial conditions at every transition from one region to another must constantly be recalculated.




**Slika 6**
Razvijeni algoritam, pojednostavljeni model

**Figure 6**
Developed algorithm, simplified model

## 4 NUMERIČKI PRISTUP

Sada će se analizirati slučaj uklapanja transformatora sa svim elementima prema slici 7. Dok se transformator još uvijek nalazi u nezasićenom području, gdje će se radi jednostavnosti induktivitet željezne jezgre označiti s $L_m$, vrijede jednadžbe:

## 4 NUMERICAL APPROACH

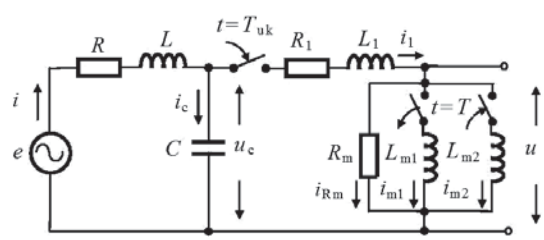
A case will now be analyzed of the energization of a transformer with all the elements according to Figure 7. While the transformer is still in the unsaturated region, where for purposes of simplicity the inductance of the iron core will be designated by $L_m$, the following equations apply:

$$e = E_m \cos \omega t = R \cdot i + L \frac{di}{dt} + u_C , \tag{18}$$

$$i = i_C + i_1 = C \frac{du_C}{dt} + i_1 , \tag{19}$$

$$i_1 = i_{Rm} + i_m = \frac{1}{R_m} u + \frac{1}{L_m} \Phi = \frac{1}{R_m} \frac{d\Phi}{dt} + \frac{1}{L_m} \Phi , \tag{20}$$

$$u_C = R_1 \cdot i_1 + L_1 \frac{di_1}{dt} + u = R_1 \cdot i_1 + L_1 \frac{di_1}{dt} + \frac{d\Phi}{dt} . \tag{21}$$




**Slika 7**
Uklapanje transformatora – potpuni model
Figure 7
Transformer energization – complete model

Transformacijom posljednje četiri jednadžbe dolazimo do diferencijalne jednadžbe četvrtog reda oblika:

Through the transformation of the last four equations, we arrive at fourth-order differential equations:

$$e = a_4 \frac{d^4 \Phi}{dt^4} + a_3 \frac{d^3 \Phi}{dt^3} + a_2 \frac{d^2 \Phi}{dt^2} + a_1 \frac{d\Phi}{dt} + a_0 \Phi , \tag{22}$$

gdje su konstante $a_i$, $i = 0, 1, 2, 3, 4$ dane sa:

where the constants $a_i$, $i = 0, 1, 2, 3, 4$ are as follows:

$$a_0 = \frac{R}{L_m} + \frac{R_1}{L_m}, \tag{22a}$$

$$a_1 = R\left(\frac{C \cdot R_1}{L_m} + \frac{1}{R_m}\right) + \frac{L}{L_m} + \frac{R_1}{R_m} + \frac{L_1}{L_m} + 1, \tag{22b}$$

$$a_2 = R \cdot C\left(\frac{R_1}{R_m} + \frac{L_1}{L_m} + 1\right) + L\left(\frac{C \cdot R_1}{L_m} + \frac{1}{R_m}\right) + \frac{L_1}{R_m}, \tag{22c}$$

$$a_3 = \frac{R \cdot C \cdot L_1}{R_m} + L \cdot C\left(\frac{R_1}{R_m} + \frac{L_1}{L_m} + 1\right), \tag{22d}$$

$$a_4 = \frac{L \cdot C \cdot L_1}{R_m}. \tag{22e}$$

Uz realne podatke [8]:

- $E_m$ = 172 kV,
- $R$ = 8,82 Ω,
- $L$ = 0,281 H,
- $C$ = 4,218 μF,
- $R_1$ = 0,529 Ω,
- $L_1$ = 0,126 H,
- $\Phi_z$ = 657,88 W,
- $L_{m1}$ = 185,24 H,
- $L_{m2}$ = 0,253 H,
- $R_m$ = 0,576 ·10$^6$ Ω,

primjenjujući Bairstow numeričku metodu, za korjene karakteristične jednadžbe bi dobili rješenja:

with real data [8]:

- $E_m$ = 172 kV,
- $R$ = 8,82 Ω,
- $L$ = 0,281 H,
- $C$ = 4,218 μF,
- $R_1$ = 0,529 Ω,
- $L_1$ = 0,126 H,
- $\Phi_z$ = 657,88 W,
- $L_{m1}$ = 185,24 H,
- $L_{m2}$ = 0,253 H,
- $R_m$ = 0,576 ·10$^6$ Ω,

and by applying the Bairstow numerical method, the roots of the characteristic equation are obtained as follows:

$$p_1 = -4{,}575 \cdot 10^6 = -\alpha, \tag{23}$$

$$p_2 = -0{,}0504 = -\beta, \tag{24}$$

$$p_{3,4} = -15{,}876 \pm \mathrm{j}919{,}096 = -\gamma \pm \mathrm{j}\omega_0. \tag{25}$$

Tada je opće rješenje jednadžbe (22):

Then the general solution of the equation (22) is:

$$\Phi(t) = a\cdot e^{-\alpha t} + b\cdot e^{-\beta t} + e^{-\gamma t}\left(c\cdot\cos\omega_0 t + d\cdot\sin\omega_0 t\right) + B\cdot\sin(\omega t + \Psi). \tag{26}$$

Očita je jaka rasutost korijena $p_1$ i $p_2$. Kada bi po analogiji na razmatranje kao u poglavlju 3 formirali matrice $\boldsymbol{M}, \boldsymbol{K}$ i $\boldsymbol{N}$, lako bismo zaključili da matrica $\boldsymbol{K}$ predstavlja singularnu matricu, jer u prvom stupcu sadrži umnoške broja $e^{p_1 T_{uk}}$. Svi ti brojevi su za računalo praktički jednaki nuli zbog goleme vrijednosti $p_1$. Dakle, klasičan analitički pristup u općem se slučaju ne bi mogao provesti zbog singularnosti matrice $\boldsymbol{K}$. U daljem dijelu razmatrat će se numerički pristup rješavanja ovog problema. Međutim, i pri numeričkom pristupu veoma je važno obratiti pozornost na izbor odgovarajućeg numeričkog postupka zbog istaknute činjenice da su korijeni karakteristične jednadžbe jako rasuti u lijevom dijelu kompleksne ravnine. Jaka disperzija korijena karakteristične jednadžbe definira zasebnu klasu diferencijalnih jednadžbi poznatih pod imenom krute diferencijalne jednadžbe (*stiff differential equations*). Naime, diskutabilna je apsolutna stabilnost numeričkih postupaka primijenjenih na ovu vrstu jednadžbi [17]. Nijedan od klasičnih numeričkih postupaka u eksplicitnoj formi, bio jednokoračni ili višekoračni tipa Eulera, Runge-Kuta, Adams-Moulton itd. pri standardnim koracima integracije, ne osigurava apsolutnu stabilnost postupka, što dovodi do divergiranja rješenja u numeričkom smislu (pogreška $\delta_k$ u $k$-toj iteraciji izaziva u $k$+1-oj iteraciji pogrešku $\delta_{k+1} > \delta_k$). Apsolutnu stabilnost osiguravaju jedino implicitni numerički postupci [17] i [18], mada i pri njihovoj upotrebi treba biti jako oprezan. U konkretnom primjeru upotrijebljeno je apsolutno stabilno implicitno trapezno pravilo.

High dispersion of the roots $p_1$ and $p_2$ is evident. If matrices $\boldsymbol{M}, \boldsymbol{K}$ and $\boldsymbol{N}$ are formed, analogically to the discussion in Chapter 3, it could be easily concluded that matrix $\boldsymbol{K}$ represents a singular matrix because it contains multiples of the number $e\, p_1 T_{uk}$ in the first column. All these numbers are practically equal to zero for a computer due to the enormous value of $p_1$. Therefore, the classical analytical approach in a general case could not be implemented due to the singularity of matrix $\boldsymbol{K}$. The numerical approach to the solution of this problem will be discussed subsequently. However, with the numerical approach it is very important to pay attention to the selection of the suitable numerical approach procedure due to the significant fact that the roots of the characteristic equation are highly dispersed in the left part of the complex plain. The high root dispersion of the characteristic equation defines a separate class of differential equations known as stiff differential equations. The absolute stability of the numerical approaches applied in this type of equation is disputable [17]. None of the classical numerical approaches in explicit form, whether of the single-step or multistep Euler, Runge-Kutta, Adams-Moulton type etc. using standard integration steps, assures the absolute stability of the procedure, which leads to divergence of the solutions in the numerical sense (error $\delta_k$ in the $k$-*th* iteration causes error $\delta_{k+1} > \delta_k$ in the $k$+1 iteration). Only implicit numerical procedures guarantee absolute stability [17] and [18], although it is necessary to use them very cautiously. In a concrete example, the absolutely stable implicit trapezoidal rule is applied.

Jednadžbe (18) do (22) će se napisati u prostoru stanja uzimajući da je vektor varijabli stanja:

Equations (18) to (22) can be written in the state space form where the state variable vector is:

$$\boldsymbol{x} = \left[i \quad u_C \quad i_1 \quad \Phi\right]^T. \tag{27}$$

Za nezasićeno područje gdje inače vrijedi:

For the unsaturated region where the following otherwise applies:

$$i_m = \frac{1}{L_{m1}}\Phi \quad \text{za / for} \quad |\Phi| \le \Phi_z, \tag{28}$$

dobiva se jednadžba u prostoru stanja: the following state space equation is obtained:

$$\dot{x} = \boldsymbol{A}_1 x + b_1, \tag{29}$$

gdje su: Where:

$$\boldsymbol{A}_1 = \begin{bmatrix} -\dfrac{R}{L} & -\dfrac{1}{L} & 0 & 0 \\ \dfrac{1}{C} & 0 & -\dfrac{1}{C} & 0 \\ 0 & \dfrac{1}{L_1} & -\left(\dfrac{R_1}{L_1}+\dfrac{R_\mathrm{m}}{L_1}\right) & \dfrac{R_\mathrm{m}}{L_1 L_\mathrm{m1}} \\ 0 & 0 & R_\mathrm{m} & -\dfrac{R_\mathrm{m}}{L_\mathrm{m1}} \end{bmatrix}, \tag{29a}$$

$$b_1 = \left[\frac{1}{L} E_\mathrm{m} \cos\omega t \;\; 0 \;\; 0 \;\; 0\right]^T . \tag{29b}$$

U zasićenom području gdje inače vrijedi relacija: In the saturated region where the following relation otherwise applies:

$$i_\mathrm{m} = \frac{1}{L_\mathrm{m2}}\Phi + \mathrm{sign}(\Phi)\left(\frac{1}{L_\mathrm{m1}} - \frac{1}{L_{m2}}\right)\Phi_\mathrm{z} \quad \text{za / for} \quad |\Phi| > \Phi_\mathrm{z}, \tag{30}$$

dobiva se: the following is obtained:

$$\dot{x} = \boldsymbol{A}_2 x + b_2, \tag{31}$$

gdje su:

where:

$$A_2 = \begin{bmatrix} -\frac{R}{L} & -\frac{1}{L} & 0 & 0 \\ \frac{1}{C} & 0 & -\frac{1}{C} & 0 \\ 0 & \frac{1}{L_1} & -\left(\frac{R_1}{L_1}+\frac{R_m}{L_1}\right) & \frac{R_m}{L_1 L_{m2}} \\ 0 & 0 & R_m & -\frac{R_m}{L_{m2}} \end{bmatrix}. \tag{31a}$$

$$b_2 = \left[\frac{1}{L}E_m \cos\omega t \;\; 0 \;\; \frac{R_m}{L_1}\mathrm{sign}(\Phi)\left(\frac{1}{L_{m1}}-\frac{1}{L_{m2}}\right)\Phi_z - R_m\,\mathrm{sign}(\Phi)\left(\frac{1}{L_{m1}}-\frac{1}{L_{m2}}\right)\Phi_z\right]^T . \tag{31b}$$

Implicitno trapezno pravilo primijenjeno na sustav $\dot{x} = A_i x + bi,\;\; i = 1, 2$ daje iteracijsku vezu:

The implicit trapezoidal rule applied to the system $\dot{x} = A_i x + bi,\;\; i = 1, 2$ yields the iteration expression:

$$x_{k+1} = \left[E - \frac{h}{2}A_i\right]^{-1}\left(\left[E + \frac{h}{2}A_i\right]x_k + \frac{h}{2}\left[b_i(t_k) + b_i(t_{k+1})\right]\right) \tag{32}$$

U posljednjoj relaciji sa $h$ označen je korak integracije i on je veoma problematičan za eksplicitne metode. Naime, da bi se osigurala stabilnost ovih postupaka korak se mora održati dovoljno malim da bi testovi stabilnosti bili zadovoljeni. Za Eulerovo pravilo je potrebno da korak integracije bude

In the previous expression, $h$ is designated as the integration step and it is highly problematic for explicit methods. In order to assure the stability of these procedures, the step should be kept sufficiently small in order to satisfy the stability tests. For Euler's rule, it is necessary for the integration step to be:

$$h \le \min_i \left\{ \frac{2\,\mathrm{Re}(\lambda_i)}{|\lambda_i|^2} \right\}, \tag{33}$$

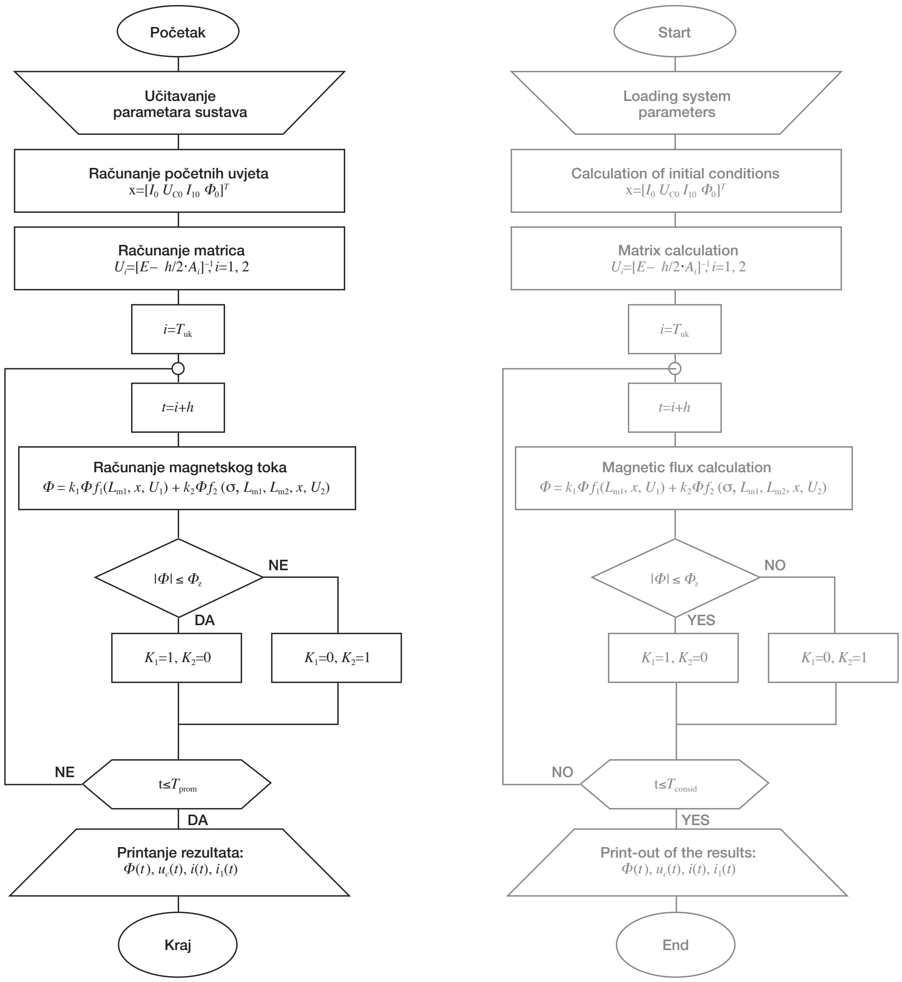
gdje su sa $\lambda_i$ označene sve svojstvene vrijednosti matrice $A_i$. Za ovaj bi primjer već za nezasićeno područje korak bio:

where $\lambda_i$ denotes all the characteristic values of matrix $A_i$. For this example, the step for the unsaturated region would be:

$$h \le \frac{2 \cdot 4{,}575 \cdot 10^6}{4{,}575^2 \cdot 10^{12}} = 4{,}37 \cdot 10^{-7} . \tag{34}$$

Pri upotrebi implicitnog trapeznog pravila nije potrebno voditi računa o veličini koraka $h$.
Dakle, moguće je načiniti algoritam, slika 8, koji će prema (32) numerički rješavati sustav diferencijalnih jednadžbi (29) za $|\Phi| \le \Phi_z$ i (31) za $|\Phi| > \Phi_z$.

When applying the implicit trapezoidal rule, it is not necessary to take the size of step $h$ into account. Therefore, it is possible to develop an algorithm, Figure 8 , which according to (32) will numerically solve the system of differential equations (29) for $|\Phi| \le \Phi_z$ and (31) for $|\Phi| > \Phi_z$.




**Slika 8**
Razvijeni algoritam, potpuni model
**Figure 8**
Developed algorithm, complete model

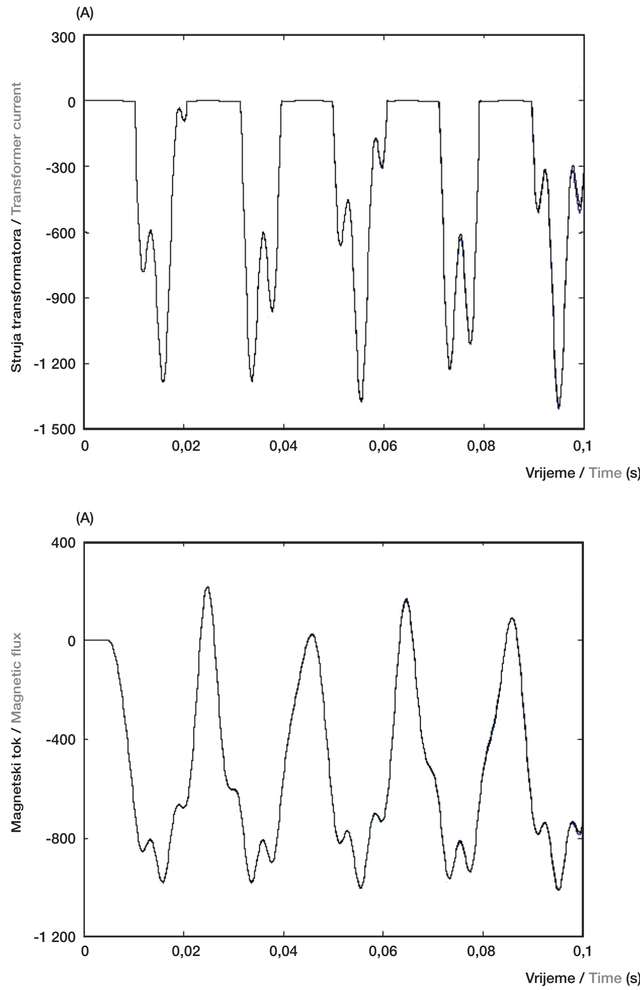
## 5 TEST PRIMJER

Programi dobiveni prema algoritmima sa slika 6 i 8 testirani su na MATLAB/Simulink/Power System Blockset (PSB), dio MATLAB-a za elektromagnetske tranzijente [19]. Parametri modela preuzeti su iz [8]. Rezultati simulacija dani su na slikama 9 i 10.

## 5 TEST EXAMPLE

The programs obtained according to the algorithms from Figures 6 and 8 have been tested using the MATLAB/Simulink/Power System Blockset (PSB), a part of MATLAB for electromagnetic transients [19]. The model parameters were taken from [8]. The simulation results are presented in Figures 9 and 10.

**Slika 9**
Pojednostavljeni model, $T_{uk}$ = 5 ms, $\Phi_{rem}$ = 0
**Figure 9**
Simplified model, $T_{uk}$ = 5 ms, $\Phi_{rem}$ = 0




Slika 9 pokazuje rezultate razvijenog algoritma koji uzima u obzir pojednostavljeni model uklapanja transformatora, bez prigušnih elemenata, poglavlje 3.

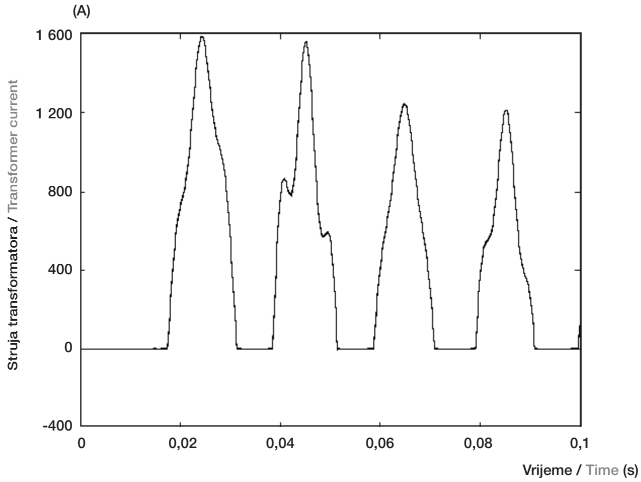
Slika 10 pokazuje rezultate razvijenog algoritma koji uzima u obzir potpuni model uklapanja transformatora, sa svim elementima, poglavlje 4. Na slici 10 je uvažen i remanentni magnetizam transformatora.

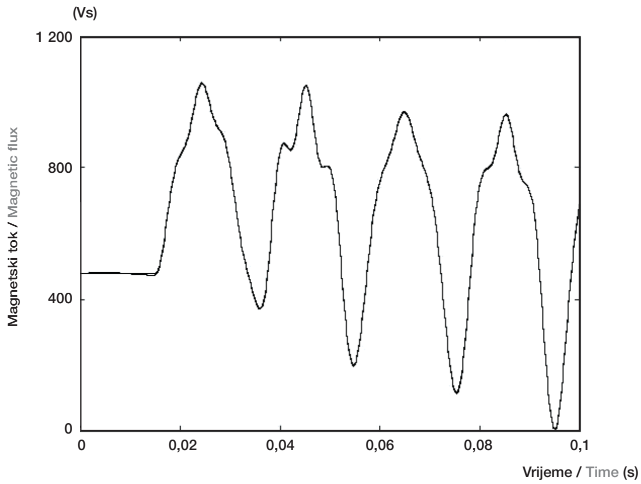
Može se zaključiti da se rezultati realiziranih programa u potpunosti podudaraju s programom PSB.

Figure 9 presents the results of the developed algorithm that takes the simplified model of transformer energization into account, without the damping elements, Chapter 3.

Figure 10 presents the results of the developed algorithm that takes the complete model of transformer energization into account, with all the elements, Chapter 4. In Figure 10, the transformer remnant magnetism has also been taken into account.

It can be concluded that the results of the realized programs are in complete agreement with the PSB program.




**Slika 10**
Potpuni model,
$T_{uk} = 15$ ms,
$\Phi_{rem} = 0{,}8\ \Phi_{nom}$

**Figure 10**
Complete model,
$T_{uk} = 15$ ms,
$\Phi_{rem} = 0{,}8\ \Phi_{nom}$

## 6 KOMPARACIJA S MJERENJIMA

Razvijeni program se može dalje generalizirati na modeliranje trofaznih transformatora, gdje su krivulje magnetiziranja predstavljene preko konačnog broja pravaca. Tada se vrijednosti struja magnetiziranja, po fazama, računaju iz formule [20]:

## 6 COMPARISON WITH MEASUREMENTS

A developed program can be further generalized for the modeling of three-phase transformers, where the magnetizing curves are represented by a finite number of straight lines. The values of the magnetizing current, according to phases, are then calculated from the following formula [20]:

$$i_{\mathrm{m}(j)_k} = \frac{\Phi_{(j)}}{L_{\mathrm{m}(j)_k}} - \mathrm{sign}\left(\Phi_{(j)}\right)\sum_{i=1}^{k-1}\Phi_{\mathrm{z}(j)_i}\left(\frac{1}{L_{\mathrm{m}(j)_i}} - \frac{1}{L_{\mathrm{m}(j)_{i+1}}}\right). \tag{35}$$

U posljednjoj relaciji su krivulje magnetiziranja, po fazama, dane s vektorima:

In the previous expression, the magnetizing curves, according to phases, are represented by vectors:

$$L_{m(j)} = \left[L_{m(j)_1}, L_{m(j)_2}, \ldots, L_{m(j)_N}\right]^T, \tag{36}$$

$$\Phi_{z(j)} = \left[\Phi_{z(j)_1}, \Phi_{z(j)_2}, \ldots, \Phi_{z(j)_N}\right]^T, \tag{37}$$

gdje su:

$j$ = 1, 2, 3 oznake faza,
$N$ = ukupni broj pravaca krivulje magnetiziranja.

Razvijeni algoritam je verificiran kompariranjem izmjerenih i simuliranih struja uklapanja neopterećenog trofaznog transformatora. Parametri trofaznog, trostupnog 2,4 kVA, 0,38/0,5 kV, Y-Y transformatora su:

– napon kratkog spoja $u_{k\%}$ = 3 %,
– djelatni otpor namota po fazi $R_{tr}$ = 1,5 Ω,
– rasipni induktivitet $L_{tr}$ = 1 mH,
– gubici u jezgri transformatora $R_m$ = 4 626 Ω.

Nelinearna krivulja magnetiziranja je predstavljena preko 13 pravaca, [20]. Pri modeliranju trostupnog transformatora uvažena je i nulta reaktancija $L_0$ = 15 mH [20].

Model transformatora [20], s pridodanom nultom reaktancijom prikazan je na slici 11.

where:

$j$ = 1, 2, 3 are phase designations,
$N$ = the total number of straight lines of the magnetizing curve.

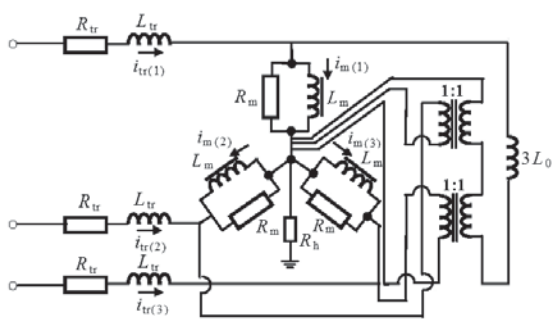
The developed algorithm is verified by compairson between the measured and simulated inrush currents of the no-load three-phase transformer. The parameters of the three-phase three-legged 2,4 kVA, 0,38/0,5 kV, Y-Y transformer are as follows:

– short-circuit voltage $u_{k\%}$ = 3 %,
– effective resistance per winding phase $R_{tr}$ = 1,5 Ω,
– leakage inductance $L_{tr}$ = 1 mH,
– iron core losses $R_m$ = 4 626 Ω.

A nonlinear magnetizing curve is presented via 13 straight lines [20]. In the modeling of a three-legged transformer, zero reactance $L_0$ = 15 mH is taken into account [20].

A transformer model [20] with added zero reactance is presented in Figure 11.

**Slika 11**
Model trofaznog, trostupnog transformatora s pridodanom nultom reaktancijom
**Figure 11**
Model of a three-phase, three-legged transformer with added zero reactance




Izvor je modeliran s vektorom elektromotorne sile po fazama:

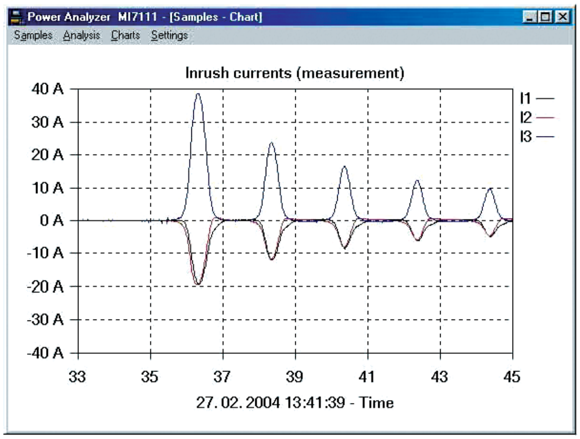
The source is modeled with a vector of the electromotive force for each phase:

$$E = \left[ 311\cos(\omega t - 34^\circ)\ ,\ 311\cos(\omega t + 86^\circ)\ ,\ 311\cos(\omega t + 206^\circ) \right]^T . \quad (38)$$

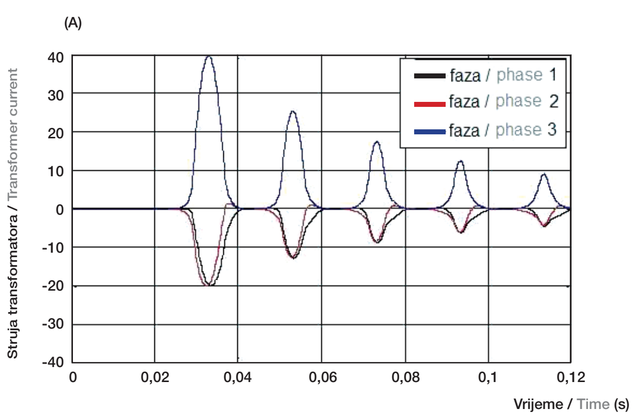
Rezultati mjerenja i simulacija dani su na slici 12.

The measurement and simulation results are presented in Figure 12.

a) Mjerenje / Measurement




b) Simulacija / Simulation




**Slika 12**
Struje uklapanja trofaznog transformatora: mjerenje i simulacija
**Figure 12**
Inrush current of a three-phase transformer: measurement and simulation

Analizom rezultata mjerenja i simulacija dolazi se do zaključka da maksimalna relativna pogreška, računata po tjemenim vrijednostima struje uklapanja tijekom svakog perioda, iznosi 3,56 %.

Through analysis of the measurement and simulation results, the conclusion is reached that the maximum relative error calculated according to the peak inrush current values during each period amounts to 3,56 %.

## 7 ZAKLJUČAK

U radu je opisan model transformatora primjenjiv u prijelaznim pojavama relativno niskih frekvencija. Za energetske transformatore velikih snaga pokazano je da se krivulja magnetiziranja kvalitativno može predstaviti preko dva pravca. Pokazane su granice upotrebe analitičkih metoda proračuna prijelaznih pojava u transformatorima. Za numeričko rješavanje sustava krutih diferencijalnih jednadžbi iskorišteno je implicitno trapezno pravilo. Razvijeni algoritam je moguće aplicirati u niskofrekvencijskim prijelaznim pojavama kao što su: uklapanje transformatora, ferorezonancija, ispad tereta, kvarovi transformatora itd. Na kraju je pokazan primjer upotrebe realiziranog algoritma na proračun prijelazne pojave uklapanja trofaznog trostupnog transformatora. Kompariranjem mjerenih i simuliranih struja uklapanja trofaznog transformatora ustanovljeno je da se pogreške nalaze u zadovoljavajućim granicama (maksimalno 3,56 %).

## 7 CONCLUSION

A transformer model applicable to relatively low frequency transient phenomena is described in the article. For power transformers with high power ratings, it was demonstrated that the magnetizing curve can be adequately presented with two straight lines. The limits for the use of analytical methods for the calculation of transient phenomena in transformers are presented. The implicit trapezoidal rule was used for the numerical solution of a system of stiff differential equations. The developed algorithm can be applied to low frequency transient phenomena such as transformer energization, ferroresonance, load switch-off, transformer faults etc. An example of the application of the developed algorithm was presented for the calculation of the transients that occur during the energization of a three-phase, three-legged transformer. Through comparison of the measured and simulated inrush currents of the three-phase transformer, it was established that the errors were within acceptable limits (a maximum of 3,56 %).

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Uredništvo primilo rukopis:
2007-07-10

Manuscript received on:
2007-07-10

Prihvaćeno:
2007-07-29

Accepted on:
2007-07-29

# REGULATORNA POLITIKA I NJEN UTJECAJ NA PLANOVE RAZVOJA I IZGRADNJE ENERGETSKIH SUBJEKATA KOJI OBAVLJAJU REGULIRANE DJELATNOSTI

# REGULATORY POLICY AND ITS IMPACT ON THE DEVELOPMENT AND CONSTRUCTION PLANS OF ENTITIES PERFORMING REGULATED ACTIVITIES

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Hrvatska energetska regulatorna agencija u prosincu 2006. godine donijela je tarifne sustave bez visine tarifnih stavki za djelatnosti proizvodnje, prijenosa, distribucije i opskrbe električnom energijom. Tarifnim sustavima utvrđena je metoda regulacije koja će se primjenjivati prilikom utvrđivanja iznosa tarifnih stavki za pojedinu djelatnost. Jedan od preduvjeta za donošenje iznosa tarifnih stavki od strane Vlade Republike Hrvatske je donošenje planova razvoja i izgradnje prijenosne i distribucijske mreže od strane energetskih subjekata koji obavljaju regulirane djelatnosti na koje Hrvatska energetska regulatorna agencija daje suglasnost.

In December 2006, the Croatian Energy Regulatory Agency – CERA (Hrvatska energetska regulatorna agencija – HERA) adopted tariff systems without stipulating the amounts of the tariff items for the activities of the generation, transmission, distribution and supply of electrical energy. A regulatory method was established through the tariff systems that will be applied in the determination of the amounts of the tariff items for individual activities. One of the prerequisites for the adoption of the amounts of tariff items by the Government of the Republic of Croatia is the adoption of the development and construction plans of the transmission and distribution networks to which the CERA issues approval.

Ključne riječi: planovi razvoja, regulatorna politika, regulatorno tijelo, regulirani energetski subjekt, tarifni sustavi

Key words: development plans, entity performing regulated activity, regulatory body, regulatory policy, tariff systems

# 1 UVOD

U prosincu 2006. godine Hrvatska energetska regulatorna agencija (HERA) donijela je tarifne sustave, bez visine tarifnih stavki za četiri djelatnosti čija se cijena utvrđuje na regulirani način [1]:

- proizvodnju električne energije s iznimkom povlaštenih kupaca,
- prijenos električne energije,
- distribuciju električne energije,
- opskrbu električnom energijom s iznimkom povlaštenih kupaca.

U navedenim tarifnim sustavima definirana je i regulatorna politika, odnosno metoda ekonomske regulacije, a to je metoda priznatih troškova poslovanja [2] do [5]. U teoretskim razmatranjima regulacije energetskih djelatnosti ova metoda svrstana je u klasični pristup regulaciji poznat i pod nazivom regulacija stopom povrata [6]. Tu metodu regulatorna tijela u državama članicama Europske unije (EU) sve više napuštaju i zamjenjuju metodama poticajne regulacije u kombinaciji s regulacijom kvalitete opskrbe [7], budući da se pokazalo da primjena regulacije stopom povrata potiče podizanje troškova ulaganja iznad onih koje bi subjekti koji obavljaju reguliranu djelatnost snosili da ulažu po kriteriju minimalnih troškova. Pokazalo se da u načelu regulacija stopom povrata postiže suprotan učinak od onog kojeg bi trebala osigurati ekonomska regulacija kroz nezavisno regulatorno tijelo. Ciljevi ekonomske regulacije prvenstveno su [7]:

- poticanje učinkovitosti i povećanje produktivnosti,
- osiguranje primjerene financijske sposobnosti sektora,
- sprječavanje diskriminacije kupaca i energetskih subjekata.

Regulatorna politika prema ulaganjima subjekata koji obavljaju regulirane djelatnosti jedan je od ključnih segmenata u provođenju ekonomske regulacije. Nova ulaganja, ako su prihvaćena kao dozvoljeni trošak, uključena su u regulatornu osnovicu sredstava, kroz amortizaciju i iznos dozvoljenog povrata sredstava. Regulatorno tijelo može imati značajnu ulogu u utvrđivanju opravdane razine ulaganja, a time i u postupku utvrđivanja cijene reguliranih djelatnosti. Tim više, ako se uzme u obzir činjenica da mnoga zakonska rješenja predviđaju da regulatorno tijelo daje suglasnost ili donosi planove razvoja subjekata koji obavljaju regulirane djelatnosti.

# 1 INTRODUCTION

In December 2006, the Croatian Energy Regulatory Agency (CERA) adopted tariff systems without stipulating the amounts of the tariff items for four activities for which the prices are determined in a regulated manner [1]:

- the generation of electrical energy, with the exception of eligible customers,
- the transmission of electrical energy,
- the distribution of electrical energy,
- the supply of electrical energy, with the exception of eligible customers.

In these tariff systems, the regulatory policy, i.e. the method of economic regulation, was defined [2] to [5]. In theoretical studies of the regulation of energy activities, this method is classified in the classical approach to regulation that is known as the rate of return ($RoR$) method [6]. This method is being increasingly abandoned by the regulatory bodies in the member countries of the European Union (EU) in favor of incentive regulation methods in combination with regulation of the quality of supply [7], since it has become evident that application of the regulation of the rate of return raises investment costs above those that entities performing regulated activities would otherwise have to pay if they invested according to the criterion of minimal costs. Furthermore, it has become evident that in principle the regulation of the rate of return achieves the opposite effect to that which should be assured by economic regulation through an independent regulatory body. The goals of economic regulation are primarily as follows [7]:

- promoting efficiency and increasing productivity,
- assuring the appropriate financial viability of the sector,
- preventing discrimination against customers and energy entities.

The regulatory policy toward the investments by entities performing regulated activities is one of the key segments in the implementation of economic regulation. New investments, if accepted as allowed expenditures, are included in the regulatory asset base ($RAB$) through depreciation and the amount of the allowed return on assets. The regulatory body, therefore, can have a significant role in determining the justified level of investment, and thereby in the procedure for the determination of the prices for regulated activities. This is even more the case when the fact is taken into account that many legal solutions anticipate that the regulatory body will issue approval or adopt the development plans of the entities performing regulated activities.

Hrvatska je na početku uvođenja ekonomske regulacije u energetskim djelatnostima, stoga se u ovom trenutku još ne mogu analizirati učinci regulatorne politike u cijelosti kao niti pojedinih regulatornih odluka. Iako su tarifni sustavi, bez visine tarifnih stavki, doneseni u prosincu 2006. godine, koliko je poznato autorima (u vrijeme predaje ovog članka uredništvu) procedura donošenja iznosa tarifnih stavki nije još započela. Za donošenje iznosa tarifnih stavki potrebno je prije svega da energetski subjekti HEP Operator prijenosnog sustava d.o.o. (HEP OPS) i HEP Operator distribucijskog sustava d.o.o. (HEP ODS) dostave HERA-i na suglasnost prijedlog trogodišnjih planova razvoja i izgradnje, a sve temeljem Zakona o tržištu električne energije [8].

Kod razmatranja planova razvoja i izgradnje prijenosne i distribucijske mreže, nameće se pitanje koje se odnosi na dubinu nadležnosti regulatornog tijela, pa tako i HERA-e, odnosno na njegovu poziciju u odnosu na davanje suglasnosti na pojedina koncepcijska rješenja, odnosno na pojedina tehnička pitanja. Naime, temeljem Zakona o tržištu električne energije [8] HEP OPS i HEP ODS donose planove razvoja i izgradnje mreža za razdoblje od tri godine tek po ishođenoj prethodnoj suglasnosti HERA-e na svoje prijedloge planova. Doneseni planovi ujedno su i ishodište za utvrđivanje iznosa tarifa. Samim zakonskim odredbama nije razvidno definirana dubina uloge HERA-e u smislu njenih ovlasti prilikom davanja tih suglasnosti.

Budući da su iskustva u Hrvatskoj u smislu utjecaja regulatornog tijela na planove razvoja i izgradnje tek u začetku, zanimljivo je analizirati ulogu drugih regulatornih tijela u donošenju planova poslovanja, tj. razvoja i izgradnje subjekata koji obavljaju regulirane djelatnosti. Iskustva regulatornih tijela članica udruženja energetskih regulatornih tijela iz Europe (*Energy Regulators Regional Association* – ERRA) [9], u kojima je regulacija i konkurentno tržište električne energije relativno novi koncept, vrlo su različita u smislu uloge regulatornog tijela u davanju suglasnosti na planove razvoja i izgradnje. U većini slučajeva regulatorna tijela ne utvrđuju kriterije planiranja razvoja prijenosne i distribucijske mreže, niti utječu na koncepcijska i tehnička rješenja koja vrlo često proizlaze iz odluka uprave tvrtki, već se njihova uloga svodi na odobravanje poslovnih planova Operatora prijenosnih sustava (OPS) i Operatora distribucijskih sustava (ODS). Paralelno odobravanju poslovnih planova, regulatorna tijela postupno uvode i razvidne kriterije kvalitete opskrbe kako bi se izbjeglo smanjenje kvalitete opskrbe zbog smanjivanja troškova kroz primjenu regulatorne metode te da bi se ujedno postiglo planiranje razvoja mreže koje za cilj ima

The Republic of Croatia is in the initial phase of introducing economic regulation into energy activities. Therefore, at this moment it is still not possible to analyze the effects of the regulatory policy in their entirety or individual regulatory decisions. For the adoption of the amounts of tariff items, it will be necessary for the HEP Transmission System Operator – HEP TSO (HEP Operator prijesnog sustava d.o.o. – HEP OPS) and the HEP Distribution System Operator – HEP DSO (HEP Operator distribucijskog sustava – HEP ODS) as energy entities to submit their proposed three-year development and construction plans to the CERA for approval, all pursuant to the Electricity Market Act [8].

When considering the development and construction plans of transmission and distribution networks, a question arises in reference to the degree of the authority of the regulatory body, and thus of the CERA, i.e. its position in relation to issuing approval for individual conceptual solutions or individual technical questions. Pursuant to the Electricity Market Act [8], the transmission system operator and the distribution system operator only adopt plans for the development and construction of networks for a period of three years after obtaining prior approval from the CERA for their proposed plans. The adopted plans are also the basis for the determination of the amounts of tariffs. The legal provisions themselves have not transparently defined the range of the CERA's role in the sense of its authority when issuing these approvals.

Since experiences in the Republic of Croatia regarding the influence of the regulatory body on development and construction plans are only in the initial phase, it is interesting to analyze the role of other regulatory bodies in the adoption of business plans, i.e. development and construction by entities performing regulated activities. The experiences of the member regulatory bodies of the Energy Regulators Regional Association (ERRA) [9], in which regulation and a competitive electrical energy market are relatively new concepts, vary considerably in the sense of the role of the regulatory body in issuing approval for development and construction plans. In the majority of cases, the regulatory bodies neither determine the criteria for planning the development of transmission and distribution networks, nor do they influence the conceptual and technical solutions that very often ensue from the decisions of company management, but instead their role is limited to approving the business plans of the transmission system operator and the distribution system operator. Together with the approval of business plans, regulatory bodies are gradually introducing transparent criteria for the quality of supply in order to avoid lowering the quality of the supply due to reduced expenditures through the application of regulatory methods in order to

povećanje učinkovitosti, odnosno povećanje kvalitete opskrbe.

Odabirom metode regulacije priznatih troškova i regulatornog razdoblja od godinu dana unutar kojeg je moguće inicirati izmjene visine tarifnih stavki, HERA nije dala naglasak na povećanje učinkovitosti subjekata koji obavljaju regulirane djelatnosti koji je jedan od glavnih ciljeva ekonomske regulacije. Imajući u vidu iskustva drugih regulatornih tijela iz EU, nužno će u skorašnje vrijeme uslijediti izmjena regulatorne metode, a time će i HERA intenzivnije pristupiti analizi ovisnosti regulatornog pristupa i razine faktora učinkovitosti primjenjujući neku od metoda poticajne regulacije. U članku se analiziraju dva regulatorna pristupa u primjeni faktora učinkovitosti i ulozi regulatornog tijela u odobravanju investicijskih planova subjekata koji obavljaju regulirane djelatnosti poznatih pod nazivom regulatorni pristup slaganja blokova (engl. *Building Blocks Appraoch*) i regulatorni pristup ukupnog troška (engl. *Total Expenditures Approach – TOTEX Approach*). O odabranom regulatornom pristupu ovisi i način na koji regulatorno tijelo ocjenjuje učinkovitost pojedinih ulaganja i razmatra opravdanost razine predviđenih ulaganja.

## 2 PRAKSA U ČLANICAMA ENERGY REGULATORS REGIONAL ASSOCIATION

Zemljopisno gledano ERRA je udruženje regulatornih tijela iz Europe (pojedine države ujedno su i članice EU) i bivših država Sovjetskog saveza osnovano 2000. godine. Trenutačno su u udruženju punopravno učlanjena 22 regulatorna tijela uključujući i HERA-u. Na sastancima odbora ERRA-e raspravlja se i razmjenjuju se iskustva o nadležnostima regulatornih tijela, problemima i izazovima s kojima se susreću regulatorna tijela. Jedna od nadležnosti većine regulatornih tijela je i sudjelovanje u postupku donošenja razvojnih/investicijskih planova energetskih subjekata koji se bave prijenosom i distribucijom električne energije u vidu tehničkih, financijskih ili poslovnih planova. Planovi se donose kao preduvjet za utvrđivanje metodologija za izračun cijena usluga ili donošenje samih iznosa cijena usluga. Pitanja koja se nameću prilikom rasprave o ulozi regulatornih tijela u donošenju predmetnih planova su:

– koliko duboko i detaljno regulatorno tijelo treba biti uključeno u izradu i donošenje razvojnih/investicijskih planova, posebice kada se radi o strateškim dilemama ili tehničkim rješenjima,

achieve the planned development of the network with the goal of improving efficiency, i.e. improving the quality of the supply.

Through the selection of the rate of return (*RoR*) method and a regulatory period of one year within which it is possible to initiate changes in the amounts of the tariff items, the CERA did not place emphasis on increasing the efficiency of the entities performing regulated activities, which is one of the main goals of economic regulation. Bearing in mind the experiences of other regulatory bodies from the EU, changes in the regulatory method will have to follow soon, and the CERA will have to intensify its analysis of the dependence of the regulatory approach and the level of the efficiency factor, applying some incentive regulation method. In this article, two regulatory approaches are analyzed in the application of the efficiency factor and the roles of the regulatory body in the approval of the investment plans of entities performing regulated activities, known as the building block approach, and the regulatory approach known as the total expenditure approach or the *TOTEX* approach. The choice of the regulatory approach will also determine the manner in which the regulatory body will assess the performance of individual investments and analyze the justification for the level of individual investments.

## 2 PRACTICES AMONG THE MEMBERS OF THE ENERGY REGULATORS REGIONAL ASSOCIATION (ERRA)

Viewed geographically, the ERRA is an association of the energy regulatory bodies from Europe (some of the countries are also members of the EU) and the former the Soviet Union, which was established in the year 2000. Currently, there are twenty-two regulatory bodies that are full members, including the CERA. At the meetings of the ERRA committees, experiences are discussed regarding the authorities of the regulatory bodies, together with the problems and challenges encountered by the regulatory bodies. One of the authorities of the majority of the regulatory bodies is participation in the procedure for the adoption of the development/investment plans of the energy entities engaged in the transmission and distribution of electrical energy, regarding technical, financial or business plans. Plans are adopted as a prerequisite for the determination of the methodologies for the calculation of the prices for services or the adoption of the amounts of the prices of the services. Questions posed during the discussions on the role of the regulatory bodies in the adoption of these plans are as follows:

– treba li regulatorno tijelo biti ta instanca koja će utvrditi jedinični trošak pojedine opreme,
– koje sastavne dijelove mora sadržavati svaki razvojni/investicijski plan.

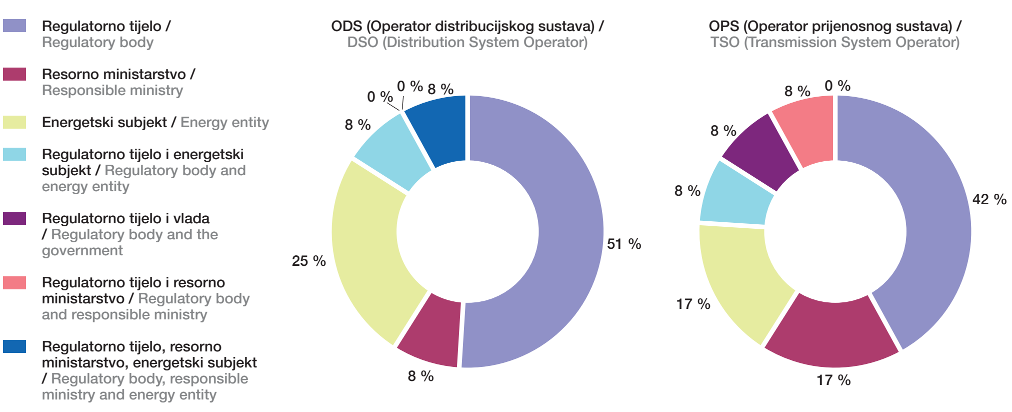
Na ova pitanja i dileme ERRA-in Odbor za tarife i cijene pokušao je u 2005. godini odgovoriti kroz analizu iskustava država članica [9]. Međutim, provedena analiza je pokazala da se uloga regulatornog tijela u donošenju razvojnih/investicijskih planova značajno razlikuje ovisno o zakonskim rješenjima, nadležnostima regulatornih tijela te stručnoj, tehničkoj i financijskoj osposobljenosti regulatornih tijela.

Upitnik koji je tom prilikom pripremljen, analiziran i prezentiran sadrži 33 pitanja. Svoje odgovore na pitanja iz Upitnika dala su regulatorna tijela iz 12 država (Armenija, Bosna i Hercegovina, Bugarska, Hrvatska, Estonija, Gruzija, Latvija, Litva, Makedonija, Poljska, Rumunjska i Ukrajina). U državama koje su odgovorile na Upitnik broj OPS-ova uglavnom je jedan, dok se broj ODS-ova kreće između 1 i više od 200 (Poljska). U većini država regulatorno tijelo daje suglasnost na razvojne/investicijske planove OPS-a i ODS-a (slika 1). Međutim, postoje i rješenja u kojima regulatorno tijelo nije uključeno u proces donošenja planova, već je to npr. u potpunosti u nadležnosti energetskih subjekata. Razdoblje na koje se donose planovi kreće se od jedne do deset godina, kako za OPS tako i za ODS.

– how deep and thorough should a regulatory body's involvement be in the preparation and adoption of development/investment plans, especially regarding strategic dilemmas or technical solutions?
– should the regulatory body be the one to define the unit costs of individual types of equipment?
– what are the integral parts that every development/investment plan should have?

In 2005, the ERRA Tariff/Pricing Committee attempted to answer these questions and dilemmas through analysis of the experiences of the member countries [9]. However, the analysis performed demonstrated that the roles of the regulatory bodies in the adoption of development/investment plans vary significantly, depending upon the legal solutions, the authorities of the regulatory bodies and the professional, technical and financial abilities of the regulatory bodies.

The questionnaire that was prepared, analyzed and presented on this occasion has thirty-three questions. The regulatory bodies from twelve countries (Armenia, Bosnia and Herzegovina, Bulgaria, Croatia, Estonia, Georgia, Latvia, Lithuania, Macedonia, Poland, Rumania and the Ukraine) answered the questions on the questionnaire. In the countries that responded to the questionnaire, the number of TSO (transmission system operators) is generally one, while the number of DSO (distribution system operators) ranges between one and over two hundred (Poland). In the majority of the countries, the regulatory body issues approval for the development/investment plans of the transmission system operators and distribution system operators (Figure 1). However, there are also solutions in which the regulatory body is not included in the process of the adoption of plans but instead, for example, the energy entities have full authorization for this. The periods for which plans are adopted range from one to ten years, for both transmission system operators and distribution system operators.




**Slika 1**
Raspodjela nadležnosti davanja suglasnosti na planove razvoja/investicija ODS-a i OPS-a u članicama ERRA-e (analiza je provedena za 12 država)

**Figure 1**
Distribution of authority for issuing approval for the development/investment plans of distribution system operators and transmission system operators among the members of ERRA. (Analysis was performed for twelve countries)

Pitanja koja su zanimljiva za ulogu regulatornog tijela u donošenju planova posebice se odnose na dubinu regulatornog utjecaja u području:

- tehničkih rješenja, npr. zamjena elektro-mehaničkih digitalnim mjernim uređajima,
- koncepcijskih dilema u razvoju visokonaponske (VN) i srednjonaponske (SN) mreže, kao što je npr. interpolacija SN/SN trafostanica,
- troška građevinskih radova,
- utvrđivanja jediničnih troškova opreme.

Prva dva područja u načelu su u većini država u nadležnosti energetskih subjekata i stvar su odluke OPS-a, odnosno ODS-a. Utvrđivanje troškova za druga dva navedena područja proizlazi iz javnih nabava. Isto tako, kada se analizira tko je nadležan za utvrđivanje kriterija za planiranje prijenosne i distribucijske mreže, proizlazi da su to prvenstveno energetski subjekti, a ne regulatorna tijela (slika 2).

Postavlja se pitanje koja je onda stvarna uloga regulatornih tijela u donošenju planova razvoja/investicija OPS-a/ODS-a, odnosno kakav utjecaj može imati regulatorno tijelo na dinamiku i visinu investicija, kao i na koncepcijska rješenja. Budući da je većina analiziranih regulatornih tijela u načelu tek u početku primjene regulatorne prakse te uspostavljanja kompetentnog i stručno osposobljenog regulatornog tijela, u većini slučajeva regulatorna uloga se svodi na analizu i nadzor financijskih i računovodstvenih izvješća, a ne na utvrđivanje kriterija za tehnička rješenja i odobravanje opravdane visine pojedinih investicija. Kao ilustrativni primjer financijskog, odnosno poslovnog, nadzora može se navesti praksa u pojedinim državama članicama ERRA-e koje su odgovorile na pitanje iz upitnika koje se odnosi na financijske i poslovne kriterije utvrđene za regulatorni nadzor energetskih subjekata.

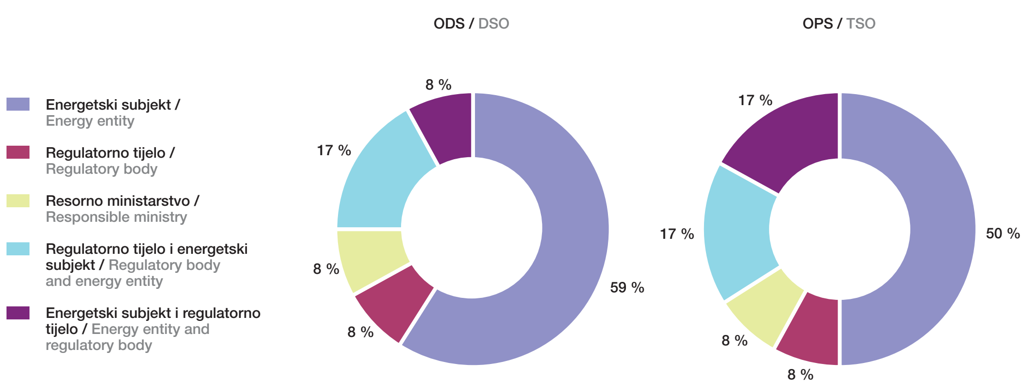
Questions of interest regarding the role of the regulatory body in the adoption of plans particularly refer to the extent of regulatory influence in the following areas:

- technical solutions, e.g. the replacement of electromechanical metering devices with digital ones,
- conceptual dilemmas in the development of high voltage and medium voltage networks, such as, for example, the interpolation of MV/MV substations,
- costs of construction work, and
- the determination of the unit costs of equipment.

In the majority of the countries, the first two areas are in principle under the authority of the energy entities and matters for decision by the transmission system operator or the distribution system operator. The definition of costs for the other two areas mentioned comes from public procurements. Similarly, it is primarily the energy entities and not the regulatory bodies which are authorized to define the criteria for the planning of transmission and distribution networks (Figure 2).

Therefore, the question is posed concerning the actual roles of the regulatory bodies in the adoption of the development/investment plans of transmission system operators and distribution system operators, i.e. what influence can a regulatory body have on the dynamics and amount of investment, as well as on the conceptual solution. Since the majority of the analyzed regulatory bodies in principle are only beginning to apply regulatory practices in the establishment of competent and professionally qualified bodies, in the majority of cases the regulatory role is limited to the analysis and audit of financial and accounting reports, and not the determination of the criteria for the technical solutions and the approval of the justified amounts of individual investments. An illustrative example of financial or operational supervision is the practice in some member countries of the ERRA which responded to the questions on the questionnaire that refer to the financial and operational criteria established for the regulatory supervision of energy entities.

**Slika 2**
Raspodjela nadležnosti za utvrđivanje kriterija za planiranje prijenosne i distribucijske mreže u članicama ERRA-e (analiza je provedena za 12 država)
**Figure 2**
The distribution of authority for the determination of criteria for the planning of transmission and distribution networks among member countries of the ERRA (analysis of 12 countries)



U Bugarskoj se financijski nadzor provodi na temelju odabranih financijskih pokazatelja koji su utvrđeni kao pokazatelji od važnosti za regulatorni nadzor. Analiza ovih pokazatelja trebala bi odgovoriti na pitanje primjenjuju li energetski subjekti mjere utvrđene od strane regulatornog tijela koje za cilj imaju povećanje ekonomske učinkovitosti proizašle iz primjene poticajne regulacije. U Latviji tarifna metodologija utvrđuje način na koji se dostavlja prijedlog tarifa, odnosno utvrđuje set potrebnih podataka koje je potrebno dostaviti regulatornom tijelu. U Ukrajini nadzor poslovnih planova provodi se kroz računovodstveni nadzor i izvješća za potrebe regulatornog tijela. Poslovni, odnosno investicijski planovi između ostalog moraju sadržavati iznos godišnjeg budžeta, izvor financiranja te detaljnu elaboraciju troškova. Za ukrajinsko regulatorno tijelo potrebno je naglasiti da već dugi niz godina primjenjuje razne vrste metoda ravnanja prema mjerilu (engl. *benchmarking*) za koje je podatak o troškovima za pojedinačne investicije više nego dobrodošao.

Odgovori na Upitnik pokazali su da u većini država regulatorno tijelo provodi nadzor nad realizacijom predviđenih investicija tijekom postupka utvrđivanja tarifa za novo regulatorno razdoblje. Ono što je bitno kod utvrđivanja cijena usluga i uključivanja pojedinih troškova u razinu prihoda energetskog subjekta odobrenog od strane regulatornog tijela je realizacija investicija iz investicijskog ciklusa. Naime, ukoliko je pojedina investicija odobrena i uključena u investicijske planove, te su za istu alocirana potrebna sredstva u regulatornom razdoblju, tu istu investiciju ne može se uključiti u regulirani trošak u novom regulatornom razdoblju. Proizlazi da je nadzor regulatornog tijela vrlo bitan u segmentu nadzora nad realizacijom investicijskih planova subjekata koji obavljaju regulirane djelatnosti.

Ukoliko energetski subjekt ne realizira predviđeni investicijski ciklus, u pojedinim državama (Armenija, Latvija, Litva, Poljska, Ukrajina), u sljedećem regulatornom razdoblju dolazi do smanjenja iznosa reguliranih tarifnih stavki. No, moguća su i drastičnija rješenja, kao npr. u Armeniji, gdje regulatorno tijelo osim smanjenja iznosa tarifnih stavki može izreći upozorenje ili oduzeti dozvolu za obavljanje energetske djelatnosti. Međutim, ukoliko se radi o OPS-u, postavlja se pitanje tko će obavljati djelatnost ukoliko se oduzme dozvola. Nadalje, kao sankcija za neispunjavanje investicijskog ciklusa, moguće su i novčane kazne, npr. u Ukrajini do 16 000 američkih dolara. I u hrvatskom zakonu [8] predviđena je novčana kazna za energetski subjekt u iznosu do 50 000 kuna ukoliko ne izrađuje planove razvoja i izgradnje, odnosno ukoliko ih ne

In Bulgaria, financial supervision is performed on the basis of selected financial indices that are determined as indices of importance for regulatory supervision. Analysis of these indices should answer the question of whether energy entities apply the measures determined by the regulatory body with the goal of achieving increased economic performance through the application of incentive regulations. In Latvia, the tariff methodology determines the manner in which a proposed tariff should be submitted, i.e. determines the set of necessary data that must be submitted to the regulatory body. In the Ukraine, supervision of business plans is performed through accounting supervision and reports for the purposes of the regulatory body. Business or investment plans, among other things, must contain the amount of the annual budget, the source of financing and a detailed elaboration of costs. For the Ukrainian regulatory body, it is necessary to emphasize that various types of methods based upon benchmarking have been applied for many years, for which data on the costs for individual investments are more than welcome.

Responses to the questionnaire showed that in the majority of the countries, the regulatory body supervises the implementation of planned investment through the procedure of determining the tariffs for the new regulatory period. What is important in the determination of the prices for services and the inclusion of individual costs in the level of the revenues of the energy entity approved by the regulatory body is the implementation of investment from the investment cycle. Insofar as an individual investment is approved and included in investment plans, and the necessary assets are allocated for it in the regulatory period, this same investment cannot be included in the regulated expenditures in the new regulatory period. Therefore, it follows that supervision by the regulatory body is very important in the segment of supervising the implementation of the investment plans of a entities performing regulated activities.

If an energy entity does not implement a planned investment cycle, in some countries (Armenia, Latvia, Lithuania, Poland and the Ukraine) there is a reduction in the amounts of the regulated tariff items in the subsequent regulatory period. However, even more drastic solutions are possible, such as, for example, in Armenia where the regulatory body, in addition to reducing the amounts of the tariff items, can also issue a warning or revoke the license for performing energy operations. However, when this concerns a transmission system operator, the question is asked who will perform the activity if the license is revoked. Furthermore, monetary fines can be imposed as penalties for not fulfilling an investment cycle such as, for example, in the Ukraine of up to USD 16 000.

izrađuje temeljem Strategije energetskog razvitka i Programa provedbe Strategije.

Radi lakše provedbe postupka davanja suglasnosti na planove od strane regulatornog tijela i kasnijeg nadzora nad provedbom planova u pojedinim državama (Bugarska i Ukrajina) struktura sadržaja planova je predefinirana. U Litvi razvojni/investicijski planovi moraju zadovoljiti nužan minimum sadržaja planova, a to je:

- obrazac potpisan od strane odgovorne osobe sa svim potrebnim podacima djelatnika (imena, telefon, e-mail adresa) koji su sudjelovali u izradi planova,
- popis planiranih investicija koje moraju biti u skladu sa strategijom razvoja i dugoročnim planovima razvoja mreža, uključujući iznos potrebnih financijskih sredstava, izvore financiranja, terminski plan i slično,
- pisano obrazloženje u vidu investicijskog plana za razdoblje od tri godine iz kojeg je vidljiv učinak pojedine investicije, kako u tehničkom tako i ekonomskom, socijalnom i ekološkom pogledu. Isto tako potrebno je navesti utjecaj pojedine investicije na cijenu, kvalitetu usluge i sl. U odgovoru na pitanje iz Upitnika nije navedeno do koje naponske razine ili koje visine investicije je potrebno pisati ovako detaljna pojašnjenja razloga za pojedinu investiciju,
- energetski subjekt treba osigurati i druge podatke ili dokumente ukoliko regulatorno tijelo ustanovi da su potrebni za mjerodavan stav regulatornog tijela.

U dijelu Upitnika koji se odnosi na povezanost planova i regulatornih parametara, kao što je to stopa povrata na kapital, većina regulatornih tijela odgovorila je da institucija koja odobrava planove ne treba predefinirati pojedine regulatorne parametre kojima bi se služili u analizi planova. Izuzetak je Bugarska u kojoj regulatorno tijelo može dati instrukcije, u smislu davanja informacije o aproksimativnom iznosu pojedinih regulatornih parametara, kao što je npr. stopa povrata na kapital kojom se energetski subjekt može koristiti prilikom izrade planova razvoja/investicija.

Under Croatian law [8], a monetary fine for an energy entity in the amount of up to 50 000 kunas is stipulated if development and construction plans are not prepared, i.e. if they are not prepared according to the Energy Development Strategy and the Program for the Implementation of the Strategy.

To facilitate implementation, the procedures for issuing approval for plans by the regulatory body and subsequent supervision of the implementation of plans in some countries (Bulgaria and the Ukraine), the structure of the content of the plans are predefined. In Lithuania, development/investment plans must include the necessary minimum contents of the plans, as follows:

- a form should be signed by the responsible persons, with all the necessary data on the employees (names, telephone numbers and e-mail addresses) who participated in the preparation of the plans,
- there should be a list of the planned investments, which must be pursuant to the development strategy and long-range plans for the development of the network, including the amount of the necessary financial assets, the sources of financing, schedule etc.,
- there should be a written explanation regarding the investment plan for the period of three years, from which the impact of individual investments is visible, in the economic, social and ecological aspects. Furthermore, it is necessary to state the impact of individual investments on price, quality of service etc. The responses to a question from the questionnaire do not indicate the voltage level or the level of investment that require a detailed written explanation of the reasons for an individual investment,
- the energy entity should also provide other data or documents if the regulatory body deems that they are necessary in order for it to determine its position.

In the part of the questionnaire that refers to the connection between plans and regulatory parameters, such as the rate of return on capital, the majority of the regulatory bodies answered that the institution that approves plans does not have to predefine the individual regulatory parameters that it would use in the analysis of the plans, with the exception of Bulgaria in which the regulatory body can provide instructions in the sense of furnishing information on the approximate amounts of regulatory parameters, such as, for example, the rate of return on capital that an energy entity can use in preparing development/investment plans.

Zaključak koji se može izvući iz odgovora na pitanja iz Upitnika je da regulatorna tijela ukoliko imaju u nadležnosti davanje suglasnosti na planove razvoja/investicija OPS-a i ODS-a, u načelu suglasnost daju na mogućnost realizacije predviđenih investicija u financijskom pogledu te na rezultate koji se postižu predviđenim investicijama. Pod rezultatima smatra se povećanje učinkovitosti subjekata koji obavljaju regulirane djelatnosti ili povećanje razine kvalitete opskrbe. Ono što je potrebno naglasiti kao zaključak razmatranja odgovora na Upitnik je da se analizirana regulatorna tijela ne miješaju u koncepcijska tehnička rješenja u planovima razvoja i izgradnje mreža.

Da bi se moglo govoriti o povećanju učinkovitosti koja je rezultat primjene poticajne regulacije i o utjecaju razine odobrenih investicija na razinu dozvoljenog prihoda reguliranog subjekta, potrebno je dati prikaz, odnosno analizu, mogućih regulatornih politika u primjeni poticajne regulacije. Pri tome važnu ulogu ima osnovica na koju se primjenjuje faktor učinkovitosti te dinamika realizacije predviđenih investicija i amortizacijska politika.

The conclusion that can be drawn from the responses to the questions on the questionnaire is that the regulatory bodies, insofar as they have the authority to approve the development/investment plans of the transmission system operator and the distribution system operator, in principle issue approval based upon the feasibility of the implementation of the planned investments in the financial aspect and based upon the results to be achieved by the planned investments. Results include the increased efficiency of the entities performing regulated activities or improved quality of the supply. It is necessary to emphasize that a conclusion drawn from a review of the responses to the questionnaire is that the analyzed regulatory bodies do not interfere in the conceptual technical solutions of the network development and investment plans.

In order to speak about the increased efficiency resulting from the application of incentive regulations and the impact of the level of approved investments on the level of the allowed revenue of entities performing regulated activities, it is necessary to provide a presentation, i.e. an analysis, of the potential regulatory policies in the application of incentive regulations. Important roles are played by the base upon which the efficiency factor is applied, the dynamics of the implementation of planned investments and the depreciation policy.

## 3 UTJECAJ REGULATORNE POLITIKE NA DOZVOLJENI PRIHOD

Do sada je bilo riječi o nadležnosti regulatornog tijela u donošenju planova razvoja/investicija, a da se pri tome nije analizirala regulatorna politika u kojoj važnu ulogu ima cilj koji se želi postići pojedinim investicijskim ciklusom te razina odobrenih investicija koje se uključuju u regulirane troškove. Kontekst regulatorne politike koji se razmatra u ovom članku prvenstveno se odnosi na poticajnu regulaciju čije su značajke u detalje razmatrane u literaturi pod [6], a za koju je, ukoliko se radi o metodi regulacije maksimalnog prihoda, karakteristična sljedeća formula:

## 3 THE IMPACT OF REGULATORY POLICIES ON ALLOWED REVENUE

Thus far, the authority of the regulatory body in the adoption of development/investment plans has been discussed without analyzing the regulatory policies, in which the desired goal to be achieved by an individual investment cycle and the level of approved investments included under regulated expenditures have important roles. The context of the regulatory policies that are discussed in this article primarily refers to incentive regulation, the characteristics of which are discussed in detail in the literature [6], and for which, insofar as they concern methods for the regulation of maximum revenue, are characterized by the following formula:

$$P_{\max t} = (1 + CPI_t - X_t) \cdot P_{\max(t-1)} - KP_t$$

$$R_{\max t} = (1 + CPI_t - X_t) \cdot R_{\max(t-1)} - KP_t \qquad (1)$$

gdje je:

$P_{\max t}$ – gornja granica dozvoljenog prihoda u godini $t$,

where:

$R_{\max t}$ – the upper limit of revenue, i.e. revenue-cap, in year $t$,

$P_{\max(t-1)}$ – gornja granica dozvoljenog prihoda u godini $t$ -1,
$CPI_t$ – indeks potrošačkih cijena u godini $t$,
$X_t$ – faktor učinkovitosti u godini $t$,
$KP_t$ – faktor korekcije u godini $t$.

Mehanizam poticajne regulacije prije svega nastoji kroz poticaje ($X$-faktor) povećati učinkovitost energetskih subjekta. Pri tome vrijedi pretpostavka da je energetski subjekt u stanju kontrolirati razinu svojih troškova. Za troškove za koje se smatra da ih energetski subjekt ne može kontrolirati, odnosno da su izvan kontrole subjekta, kao što su to npr. porezi, naknada za regulaciju, troškovi koje je prouzročila viša sila i sl., ne može se očekivati povećanje učinkovitosti subjekta na račun njihovog smanjenja. Stoga se poticaji primjenjuju na razinu kontroliranih troškova, dok se nekontrolirani troškovi smatraju prolaznim i u cjelokupnom iznosu se prebacuju na kupca. Detaljna elaboracija granice između kontroliranih i nekontroliranih troškova zahtijeva dublje analize od strane regulatornog tijela. Kao primjer troškova koji se mogu svesti u sferu kontroliranih i nekontroliranih troškova su troškovi tehničkih gubitaka u mreži. Ukoliko regulatorno tijelo smatra da su gubici u potpunosti nekontrolirani trošak, prihvaća njihovu razinu, odnosno njihov trošak, u iznosu koji prijavljuje energetski subjekt. U tom slučaju energetski subjekt neće imati nikakav poticaj da ih smanji, bilo u vidu troška bilo u vidu fizičkih gubitaka izraženih u kWh. Međutim, ukoliko ih regulatorno tijelo smatra kontroliranim troškom, nastojat će ih kroz regulatornu politiku svesti u granice koje se sa stajališta regulatornog tijela čine opravdanima.

Kada se radi o kontroliranim troškovima, regulatorna politika razlikuje dvije grupe troškova:

- operativne troškove (engl. *Operating Expanditures – OPEX*), troškovi koje je moguće kontrolirati u kratkoročnom razdoblju i
- kapitalne troškove (engl. *Capital Expanditures – CAPEX*), troškove koje je moguće kontrolirati u dugoročnom razdoblju.

U *OPEX* se ubrajaju troškovi osoblja, materijalni troškovi, troškovi održavanja, ostali troškovi poslovanja i sl. Troškovi koje je moguće prilagođavati u relativno kratkom roku. S druge pak strane, *CAPEX* se u kratkoročnom razdoblju može promatrati kao fiksni trošak budući da se i prvenstveno radi o troškovima koji se vežu uz investicije u razvoj mreža i poboljšanje kvalitete opskrbe. *CAPEX* je moguće podijeliti u dvije grupe – amortizaciju i povrat sredstava koji se definira kao godišnja stopa povrata primijenjena na neamortizirani dio ulaganja. Povrat sredstava u načelu utvrđuje regulator-

$R_{\max(t-1)}$ – the upper limit of revenue, i.e. revenue-cap, in year $t$ -1,
$CPI_t$ – the consumer price index in year $t$,
$X_t$ – the efficiency factor in year $t$,
$KP_t$ – the correction factor in year $t$.

The mechanism of incentive regulation primarily attempts to increase the efficiency of energy entities through incentives (the $X$-factor). It is presumed that an energy entity is in a position to control the level of its expenditures. For expenditures presumed to be non-controllable by an energy entity, i.e. that are out of the control of the entity, such as, for example, taxes, regulation charges, expenditures due to force majeure etc., it is not possible to expect that the entity will achieve increased efficiency by reducing them. Therefore, incentives are applied at the level of controllable costs, while non-controllable costs are considered to be transitory and are transferred in their entirety to the customers. A detailed elaboration of the boundary between controllable and non-controllable expenditures requires in-depth analysis by the regulatory body. An example of expenditures that can be classified within the spheres of both controllable and non-controllable expenditures are the costs of technical losses in the network. Insofar as the regulatory body considers the losses to be entirely non-controllable expenditures, it accepts their level, i.e. their cost, in the amount that the energy entity reports. In this case, the energy entity will not have any incentive to reduce them, whether in the aspect of expenditures or the aspect of physical losses expressed in kWh. However, insofar as the regulatory body considers them to be controllable expenditures, it will attempt to lower them through regulatory policy to within the limits considered justified from the standpoint of the regulatory body.

Concerning controllable expenditures, regulatory policy differentiates between two groups of expenditures:

- Operating expenditure – *OPEX*, expenditure that can be controlled within a short-term period
- Capital expenditure – *CAPEX*, expenditure that can be controlled within a long-term period.

Under *OPEX* are included personnel costs, material costs, maintenance costs, other operating costs etc. These are expenditures that can be adjusted within a relatively short period. On the other hand, *CAPEX* can be considered as fixed expenditures within a short-term period, primarily concerning expenditures in connection with investment in network development and improvement in the quality of the supply. *CAPEX* can be divided into two groups – depreciation and return on assets, defined as the annual rate of return applied to the non-depreciated portion of investment. In principle, the return

no tijelo na osnovi troška kapitala subjekata koji obavljaju regulirane djelatnosti [7].

Imajući u vidu da regulatorno tijelo u načelu može regulirati dvije kategorije troškova, moguće je definirati dva pristupa u regulaciji. Prvo, regulatorno tijelo može primjenjujući pojedinu metodu poticajne regulacije zasebno razmatrati *OPEX* i *CAPEX*. Ovakav pristup poznat je pod nazivom regulatorni pristup slaganja blokova, budući da se sastoji od dvije komponente, odnosno bloka, za koje regulatorno tijelo pojedinačno utvrđuje opravdanu razinu.

Drugi pristup se odnosi na regulatornu politiku u kojoj regulatorno tijelo *OPEX* i *CAPEX* razmatra kao integrirani trošak na koji se sumarno primjenjuje odabrana metoda poticajne regulacije. Ovakav pristup poznat je pod nazivom regulatorni pristup ukupnog troška. *TOTEX* označava sumu *OPEX*-a i *CAPEX*-a. U nastavku razmatra se svaki od pristupa pojedinačno.

### 3.1 Regulatorni pristup slaganja blokova

U regulatornom pristupu slaganja blokova regulatorno tijelo mora odvojeno analizirati učinkovitu, odnosno opravdanu razinu, *OPEX*-a i *CAPEX* -a. Pri ocjenjivanju razine učinkovitosti i opravdanosti *OPEX*-a čest je slučaj da regulatorna tijela koriste razne metode ravnanja prema mjerilu [7]. Međutim, utvrđivanje faktora učinkovitosti $X$ u formuli za poticajnu regulaciju (1) zahtijeva puno složeniji postupak, uključujući i diskrecijske odluke regulatornih tijela, od direktnog uvrštavanja rezultata dobivenih primjenom neke od poznatih metoda ravnanja prema mjerilu.

Dozvoljena razina *CAPEX*-a utvrđuje se na osnovi investicijskih planova energetskih subjekata predviđenih za sljedeće regulatorno razdoblje. Na osnovi predloženih investicija, regulatorno tijelo procjenjuje koje investicije uključiti u regulatornu osnovicu sredstava. Investicije koje su uključene u regulatornu osnovicu sredstava bit će u potpunosti uključene u trošak amortizacije te će se na neamortizirani dio primijeniti stopa povrata na uloženi kapital.

Čest je slučaj da se predviđena razina investicija promatra kao trošak koji se prihvaća na razini prijedloga energetskih subjekata. Ukoliko regulatorno tijelo u potpunosti prizna predložene investicije, kod energetskog subjekta se stvara poticaj da prikazuje što veću razinu budućih investicija ne vodeći se opravdanim razlozima kao što su smanjenje gubitaka u mreži ili postizanje optimalne, odnosno propisane razine kvalitete opskrbe. Pri tome energetski subjekt ima u vidu da će se veća

on assets is determined by the regulatory body on the basis of the capital expenditures of the entities performing regulated activities [7].

Bearing in mind that the regulatory body can in principle regulate the two categories of expenditures, it is possible to define two approaches to regulation. First, when the regulatory body applies an individual incentive regulation method, it can consider *OPEX* and *CAPEX* separately. Such an approach is known as the building block approach, since it consists of two components, i.e. blocks, for which the regulatory body determines the justifiable levels individually.

The second approach refers to the regulatory policy in which the regulatory body considers *OPEX* and *CAPEX* as an integrated expenditure, to which the selected incentive regulation method is summarily applied. Such an approach is known as the total expenditure, *TOTEX*, regulatory approach. *TOTEX* represents the sum of *OPEX* and *CAPEX*. Each approach will be discussed separately.

### 3.1 The building block regulatory approach

In the building block regulatory approach, the regulatory body must analyze the efficiency or justified level of *OPEX* and *CAPEX* separately. In assessing the efficiency and justified level of *OPEX*, a regulatory body frequently employs various benchmarking methods [7]. However, the determination of the efficiency factor $X$ in the formula for incentive regulation (1) requires a far more complex procedure, including discretional decisions by the regulatory bodies, such as the direct classification of the results obtained from the application of some of the well-known benchmarking methods.

The allowed level of *CAPEX* is determined on the basis of the investment plans of energy entities for the subsequent regulatory period. On the basis of the proposed investments, the regulatory body assesses which investments to include in the regulatory asset base (*RAB*). Investments that are included in the regulatory asset base will be fully included in the depreciation cost, and the return rate on invested capital will be applied to the non-depreciated part.

It is frequently the case that the investment level is considered as an expenditure which is accepted at the level of the proposals by the energy entities. Insofar as the regulatory body recognizes the proposed investments in full, incentive is created for the energy entity to show the highest possible level of future investments, whether or not they are based upon justified reasons such as reducing losses in the network or achieving the optimal, i.e.

razina investicija uključiti u regulatornu osnovicu sredstava, a time će biti i veći povrat sredstava, što će se u konačnici odraziti i na profite. Energetskom subjektu bit će u interesu prikazati što veće investicije u budućem regulatornom razdoblju. Povodeći se tim načelom postoji i mogućnost da pojedine *OPEX* troškove energetski subjekt prikaže kao *CAPEX*. Na taj način pojedini *OPEX* troškovi nisu uključeni u poticajni mehanizam povećanja učinkovitosti na razini *OPEX* troškova. Time će se postići privid manjih *OPEX* troškova, odnosno postizanje veće učinkovitosti energetskog subjekta u sferi *OPEX* troškova. Strateška alokacija *OPEX*-a pod *CAPEX*, odnosno povećanje regulatorne osnovice sredstava na taj način, uočena je već u nekim slučajevima regulatornog nadzora posebice u Velikoj Britaniji [10].

Postavlja se pitanje na koji način regulatorno tijelo može reagirati ukoliko se tijekom regulatornog razdoblja ne realiziraju sve predviđene investicije odobrene od strane regulatornog tijela. Ukoliko se pokaže da nisu realizirane sve predviđene investicije, regulatorno tijelo može u sljedećem regulatornom razdoblju utvrditi niže cijene usluga, odnosno može ne dozvoliti ponovno uključivanje nerealiziranih investicija u regulatornu osnovicu sredstava. Međutim, da bi regulatorni pristup bio dosljedan i razvidan za obje strane, regulatorno tijelo i energetski subjekt, regulatorno tijelo može utvrditi donju i gornju granicu za realizaciju investicija iz plana poslovanja i razvoja. Prekomjerne investicije neće biti uopće uključene u regulatornu osnovicu sredstava ili će biti uključene samo djelomično. Ono što predstavlja problem u takvom regulatornom pristupu je da energetski subjekt nema poticaja za povećanje učinkovitosti u segmentu *CAPEX* -a. Naime, ukoliko se ostvari manji *CAPEX* od predviđenog, regulatorno tijelo će u načelu u budućem regulatornom razdoblju kao osnovicu za izračun imati manji *CAPEX*, bez obzira da li se radi o uštedama na račun podinvestiranosti (manjeg razmjera investicija od odobrenih) ili o povećanju produktivnosti energetskog subjekta. Energetski subjekt ne ostvaruje nikakve financijske koristi od povećanja učinkovitosti u segmentu *CAPEX* -a.

the stipulated, level of supply quality. The energy entity must bear in mind that a higher level of investment will be included in the regulatory asset base and, therefore, there will be a greater return on assets, which will ultimately reflect upon profits. Consequently, it is in the interest of the energy entity to show the maximum investments in the future regulatory period. Consequently, there is also the possibility that an individual *OPEX* by an energy entity is shown as a *CAPEX*. In this manner, individual operating expenditures are not included in the incentive mechanism for increasing efficiency at the level of *OPEX*. In this manner, apparently lower operating expenditures will be achieved, i.e. greater efficiency of the energy entity in the sphere of *OPEX*. The strategic allocation of operating expenditures under capital expenditures, i.e. increasing the regulatory asset base in this manner, has already been noted in some cases of regulatory supervision, especially in Great Britain [10].

The question is posed regarding how a regulatory body can react if all the planned investments that it has approved have not been made during a regulatory period. Insofar as all the planned investments have not been implemented, during the subsequent regulatory period the regulatory body can set lower prices for services or can prohibit non-implemented investments from being included in the regulatory asset base again. However, in order for the regulatory procedure to be consistent and transparent for both sides, the regulatory body and the energy entity, the regulatory body can set lower and upper limits for the implementation of investment from the business and development plans. Excessive investment will not be included in the regulatory asset base or will be included only in part. What represents a problem in such a regulatory approach is that an energy entity does not have any incentive to increase efficiency in the *CAPEX* segment. If there is lower *CAPEX* than anticipated, in principle the regulatory body will have lower *CAPEX* as a base for calculation in the subsequent regulatory period, regardless of whether this concerns savings at the expense of under investment (lower investment than approved) or increased productivity by the energy entity. Therefore, the energy entity does not derive any financial benefits from increasing efficiency in the *CAPEX* segment.

Tablica 1 – Pojednostavljen primjer izračuna dozvoljenog prihoda primjenom regulatornog pristupa slaganja blokova
Table 1 – Simplified example of the calculation of the allowed revenue through the application of the building block regulatory approach

| **Regulatorni parametri / Regulatory parameters** | |
|---|---|
| *OPEX* – faktor učinkovitosti / *OPEX* – efficiency factor | 90 % |
| Godišnje smanjenje *OPEX*-a / Annual reduction in *OPEX* | 2,60 % |
| Razdoblje amortizacije (godina) / Depreciation period (years) | 20 |
| Stopa povrata / Rate of return | 7 % |

| | Godine / Year | | | | |
|---|---|---|---|---|---|
| | 0. | 1. | 2. | 3. | 4. |
| | ($10^6$ HRK) | ($10^6$ HRK) | ($10^6$ HRK) | ($10^6$ HRK) | ($10^6$ HRK) |
| **Odobrene investicije / Authorized investments** | | 1 000,00 | 1 200,00 | 1 000,00 | 1 400,00 |
| | | | | | |
| Odobrena amortizacija / Authorized depreciation | | | | | |
| – od prethodnih investicija / from previous investments | | 700,00 | 700,00 | 700,00 | 700,00 |
| – od investicija iz 1. godine / from investments from the 1st year | | 50,00 | 50,00 | 50,00 | 50,00 |
| – od investicija iz 2. godine / from investments from the 2nd year | | | 60,00 | 60,00 | 60,00 |
| – od investicija iz 3. godine / from investments from the 3rd year | | | | 50,00 | 50,00 |
| – od investicija iz 4. godine / from investments from the 4th year | | | | | 70,00 |
| **– Ukupno odobrena amortizacija / Total authorized depreciation** | | 750,00 | 810,00 | 860,00 | 930,00 |
| | | | | | |
| **Izračun regulatorne osnovice (*ROS*) / Calculation of the regulatory asset base (*RBA*)** | | | | | |
| – početni *ROS* / initial *RBA* | | 3 000,00 | 3 250,00 | 3 640,00 | 3 780,00 |
| – plus: nove investicije / plus: new investments | | 1 000,00 | 1 200,00 | 1 000,00 | 1 400,00 |
| – minus: amortizacija / minus: depreciation | | 750,00 | 810,00 | 860,00 | 930,00 |
| – konačni *ROS* / final *RBA* | 3 000,00 | 3 250,00 | 3 640,00 | 3 780,00 | 4 250,00 |
| **– prosječni *ROS* / mean *RBA*** | | 3 125,00 | 3 445,00 | 3 710,00 | 4 015,00 |
| | | | | | |
| **Izračun ukupnog dopuštenog prihoda / Calculation of total authorized revenue** | | | | | |
| – *OPEX* / *OPEX* | 2 400,00 | 2 337,60 | 2 276,82 | 2 217,63 | 2 159,97 |
| – amortizacija / depreciation | 700,00 | 750,00 | 810,00 | 860,00 | 930,00 |
| – povrat sredstava (stopa povrata **ROS*) / return on assets (return rate **RBA*) | 210,00 | 218,75 | 241,15 | 259,70 | 281,05 |
| **– dozvoljeni prihod / allowed revenue** | 3 310,00 | 3 306,35 | 3 327,97 | 3 337,33 | 3 371,02 |

Nadalje, problem koji se javlja prilikom uspostave ciljane razine investicija je da ta razina mora odražavati učinkovitu razinu svake pojedine investicije koja se uključuje u regulatornu osnovicu sredstava. Da bi ovakav pristup bio moguć, regulatorno tijelo mora imati dovoljnu količinu informacija kao i dovoljan broj stručno osposobljenih ljudi, što se u praksi često pokazalo neostvarivim. Problem se dodatno komplicira budući da je primjena neke od metoda ravnanja prema mjerilu na *CAPEX* -a poprilično složen i težak postupak za primjenu, stoga ga regulatorna tijela izbjegavaju. Polazište za definiranje investicijskog plana

Furthermore, a problem that arises when establishing a target level of investment is that it must reflect the level of the performance of each individual investment that is included in the regulatory asset base. In order for this approach to work, the regulatory body must have a sufficient amount of information as well as a sufficient number of qualified personnel, which in practice is often unfeasible. The problem is additionally complicated because the application of some benchmarks to *CAPEX* is a fairly complex and difficult procedure and, therefore, regulatory bodies avoid it. The starting point for the definition of an investment plan is growth in consumption and the

je porast potrošnje te zamjena postojeće opreme. Ti čimbenici se razlikuju kada je riječ o različitim energetskim subjektima te mogu značajno utjecati na rezultate primjene metode ravnanja prema mjerilu. Nadalje, iako se radi o istovrsnim investicijama i istoj razini investicija, na rezultate metoda ravnanja prema mjerilu može utjecati i različito vrijeme započinjanja investicije i dinamika realizacije investicije, kao i utvrđena razina kvalitete opskrbe. Kvaliteta opskrbe kao funkcija regulacije do sada se često promatrala kao zasebna funkcija od funkcije regulacije cijena usluga, iako iskustva pokazuju da regulatorna tijela sve više nastoje razviti integrirane modele regulacije kojima bi se izbjegli svi dosadašnji rizici primjene pojedine metode regulacije [9]. Tablica 1 prikazuje pojednostavljeni primjer izračuna dozvoljenog, odnosno od strane regulatornog tijela odobrenog prihoda regulatornim pristupom slaganja blokova. Vrijednosti za dozvoljene investicije (na godišnjoj razini od 1 000 milijuna kuna), početni *OPEX* (2 400 milijuna kuna) i amortizaciju od prethodnih investicija (700 milijuna kuna) koje su pri tome korištene na razini su vrijednosti HEP ODS-a [12]. Od vrijednosti prikazanih u literaturi pod [12] oduzeti su troškovi koji po procjeni autora otpadaju na priključke. Od regulatornih parametara utvrđeni su:

- regulatorno razdoblje od 4 godine,
- faktor učinkovitosti za *OPEX* u vrijednosti 90 %, što godišnje iznosi smanjenje *OPEX*-a 2,6 %,
- linearna amortizacija na razdoblje od 20 godina,
- stopa povrata od 7 %.

Iz tablice 1 vidljivo je da, ukoliko se svi parametri definiraju kako je prethodno rečeno, dozvoljeni prihod subjekata koji obavljaju regulirane djelatnosti kroz 4 godine regulatornog razdoblja ostaje na skoro istoj razini. Regulatorna politika, odnosno ocjena potrebne razine povećanja učinkovitosti, može imati značajan utjecaj na regulirani prihod energetskog subjekta.

### 3.2 Regulatorni pristup ukupnih troškova

U regulatornom pristupu ukupnih troškova regulatorno tijelo kada utvrđuje razinu opravdane učinkovitosti ne razlikuje između *OPEX*-a i *CAPEX* -a, stoga faktor učinkovitosti *X* primjenjuje na sumu *OPEX*-a i *CAPEX*-a, odnosno na ukupan trošak (*TOTEX*) (tablica 2). U ovom slučaju regulatorno tijelo ne mora utvrđivati odvojeno opravdanu razinu investicija za sljedeće regulatorno razdoblje, već analizu provodi za ukupne troškove. U ovom pristupu regulatorno tijelo utvrđuje *X*-faktor na osnovi razine učinkovitosti iz prethodnih regulator-

replacement of existing equipment. These factors differ among various energy entities and can significantly influence the results of the benchmarking method applied. Moreover, although this concerns the same types of investments and the same level of investment, the results of the benchmarking method can be affected by differing times for the beginning of investments and the dynamics of the implementation of the investments, as well as the determined level of the quality of the supply. Up to now, the quality of the supply as a function of regulation has been frequently viewed as a function that is separate from the function of the regulation of the prices for services, although experience shows that the regulatory bodies are increasingly attempting to develop integrated models of regulation that avoid all the risks inherent in the individual regulatory methods that have been applied [9]. Table 1 shows a simplified example of the calculation of allowed revenue, i.e. revenue authorized by the regulatory body, using the building block approach. The values for allowed investments (at an annual level of 1 000 million kunas), the initial *OPEX* (2 400 million kunas) and depreciation from previous investments (700 million kunas) were previously used at the level of the HEP Distribution System Operator (HEP ODS d,o.o.) [12]. From the values presented in the literature under [12], expenditures have been deducted that the authors consider to be connection costs. The following regulatory parameters have been established:

- a regulatory period of 4 years,
- a efficiency factor for *OPEX* with a value of 90 %, which amounts to an annual reduction in *OPEX* of 2,6 %,
- linear depreciation during a period of 20 years,
- a rate of return of 7 %.

From Table 1, it is evident that, when all the parameters are defined as above, the allowed revenue of a entities performing regulated activities during a 4-year regulatory period remains at nearly the same level. Thus, regulatory policy, i.e. the assessment of the necessary level of increasing efficiency, can have a significant impact on the regulated revenue of an energy entity.

### 3.2 The regulatory approach of total expenditure

In the regulatory approach of total expenditure, when the regulatory body determines the level of justified efficiency it does not differentiate between *OPEX* and *CAPEX*, and therefore the efficiency factor *X* is applied to the sum of *OPEX* and *CAPEX*, i.e. to the total expenditure (*TOTEX*) (Table 2). Therefore, in this case the regulatory body does not need to determine the justified levels of investment separately for the subsequent regulatory period but

nih razdoblja. Ukoliko je energetski subjekt uspio u prethodnim razdobljima podići razinu učinkovitosti, koju će zadržati i u budućem razdoblju, *X*-faktor će biti niži. Naime, ovo je značajna razlika u regulatornom pristupu u odnosu na pristup slaganja blokova u kojem se prije svega ocjenjuje opravdanost razine predviđenih investicija u budućem razdoblju, ali ne i učinkovita razina *CAPEX* -a.

analyzes the total expenditure instead. In this approach, the regulatory body determines the *X*-factor on the basis of the level of efficiency from the previous regulatory periods. If the energy entity has successfully achieved the specified level of efficiency during the previous periods, which will also be maintained during the future period, the *X*-factor will be lower. This is a significant difference in the regulatory approach in comparison to the building block approach, in which the justification of the level of the anticipated investments in the future period is assessed but not the efficiency level at the *CAPEX* level.

Tablica 2 – Pojednostavljen primjer izračuna dozvoljenog prihoda primjenom regulatornog pristupa ukupnog troška
Table 2 – A simplified example of the calculation of the allowed revenue through the application of the total expenditure regulatory approach

| **Regulatorni parametri / Regulatory parameters** | |
|---|---|
| Ukupni faktor učinkovitosti / Total efficiency factor | 88 % |
| Godišnja stopa porasta učinkovitosti / Annual rate of efficiency growth | 4 % |

| | **Godina / Year** | | | |
|---|---|---|---|---|
| | 0. | 1. | 2. | 3. |
| | ($10^6$ HRK) | ($10^6$ HRK) | ($10^6$ HRK) | ($10^6$ HRK) |
| *OPEX* / *OPEX* | 2 400,00 | 2 304,00 | 2 212,00 | 2 123,00 |
| Amortizacija / Depreciation | 700,00 | 672,00 | 645,00 | 619,00 |
| Povrat sredstava / Return on assets | 300,00 | 288,00 | 276,00 | 265,00 |
| **Dozvoljeni prihod / Allowed revenue** | 3 400,00 | 3 264,00 | 3 133,00 | 3 008,00 |

U ovom pristupu problem ocjenjivanja opravdanosti razine investicija je na svojevrstan način izbjegnut. Nadalje, budući da ovaj pristup ne razlikuje *OPEX* i *CAPEX*, moguće je da energetski subjekt postigne odgovarajuću razinu učinkovitosti balansirajući između *OPEX*-a i *CAPEX* -a, odnosno između, u klasičnom smislu teorije produktivnosti, rada i kapitala. Kod regulatornog pristupa ukupnih troškova, regulatorno tijelo ne mora razvijati kriterije za ocjenjivanje prijedloga investicija, već analizira *TOTEX*, koji uključuje i investicije, te utvrđuje *X*-faktor na osnovi analize *TOTEX*-a.

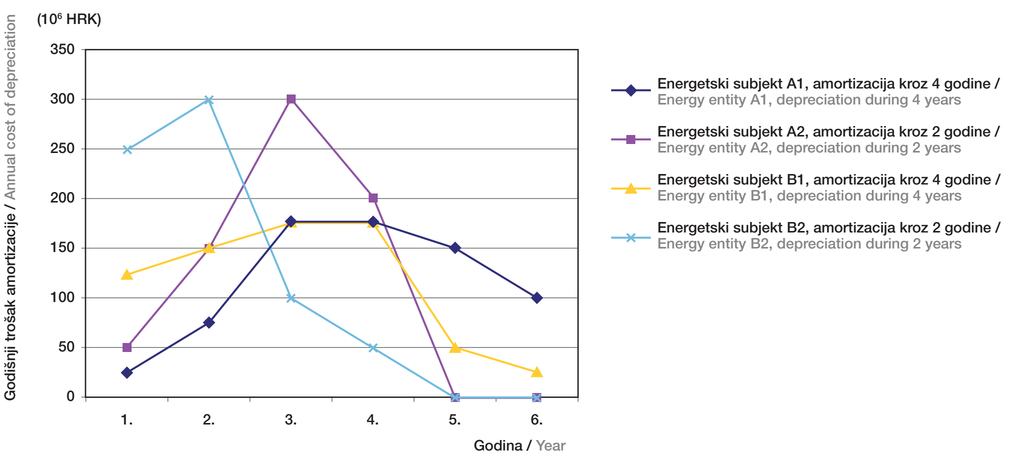
In this approach, the problem of assessing the justification of the level of investment is avoided in its own way. Furthermore, since this approach does not differentiate between *OPEX* and *CAPEX*, it is possible for an energy entity to achieve the suitable level of efficiency by balancing *OPEX* and *CAPEX* or labor and capital, in the classical sense of the theory of productivity. Therefore, in the regulatory approach of total expenditure, the regulatory body does not have to develop criteria for the assessment of an investment proposal but instead analyzes *TOTEX*, which also includes investment, and determines the *X*-factor on the basis of analysis of the *TOTEX*.

Tablica 3 – Pojednostavljen primjer utjecaja različite dinamike investiranja i amortizacijske politike na godišnji trošak amortizacije
Table 3 – A simplified example of the influence of various dynamics of investment and depreciation policies on the annual depreciation cost

| Godina / Year | Investicije / Investments ($10^6$ HRK) | Godišnji trošak amortizacije po investicijama / Annual depreciation cost according to investments ($10^6$ HRK) | | | Troškovi amortizacije / Depreciation costs ($10^6$ HRK) |
|---|---|---|---|---|---|
| **Energetski subjekt A1, amortizacija kroz 4 godine / Energy Entity A1, depreciation during 4 years** | | | | | |
| | | 1. | 2. | 3. | |
| 1. | 100 | 25 | | | 25 |
| 2. | 200 | 25 | 50 | | 75 |
| 3. | 400 | 25 | 50 | 100 | 175 |
| 4. | | 25 | 50 | 100 | 175 |
| 5. | | | 50 | 100 | 150 |
| 6. | | | | 100 | 100 |
| **Ukupno / Total** | 700 | 100 | 200 | 400 | 700 |
| | | | | | |
| **Energetski subjekt A2, amortizacija kroz 2 godine / Energy Entity A2, depreciation during 2 years** | | | | | |
| 1. | 100 | 50 | | | 50 |
| 2. | 200 | 50 | 100 | | 150 |
| 3. | 400 | | 100 | 200 | 300 |
| 4. | | | | 200 | 200 |
| 5. | | | | | 0 |
| 6. | | | | | 0 |
| **Ukupno / Total** | 700 | 100 | 200 | 400 | 700 |
| | | | | | |
| **Energetski subjekt B1, amortizacija kroz 4 godine / Energy Entity B1, depreciation during 4 years** | | | | | |
| 1. | 500 | 125 | | | 125 |
| 2. | 100 | 125 | 25 | | 150 |
| 3. | 100 | 125 | 25 | 25 | 175 |
| 4. | | 125 | 25 | 25 | 175 |
| 5. | | | 25 | 25 | 50 |
| 6. | | | | 25 | 25 |
| **Ukupno / Total** | 700 | 100 | 200 | 400 | 700 |
| | | | | | |
| **Energetski subjekt B2, amortizacija kroz 2 godine / Energy Entity B2, depreciation during 2 years** | | | | | |
| 1. | 500 | 250 | | | 250 |
| 2. | 100 | 250 | 50 | | 300 |
| 3. | 100 | | 50 | 50 | 100 |
| 4. | | | | 50 | 50 |
| 5. | | | | | 0 |
| 6. | | | | | 0 |
| **Ukupno / Total** | 700 | 500 | 100 | 100 | 700 |

Problem koji se javlja u regulatornom pristupu ukupnih troškova je vezan uz ročnost investicija. Naime, *CAPEX* se, uključujući amortizaciju i povrat sredstava, proteže kroz niz godina. Stoga bi prilikom primjene metoda ravnanja prema mjerilu analiza trebala u obzir uzeti razdoblje od nekoliko godina, a ne da se provodi na troškovima predviđenim samo za jednu godinu. Kao ilustrativni primjer dan je prikaz u kojem na *CAPEX* značajno utječe dinamika realizacije investicije, pri tome je prikazan samo trošak amortizacije, ali ne i povrat sredstava (tablica 3). Ukoliko bi se u analizi promatrala samo jedna godina, npr. druga godina realizacije investicije, energetski subjekt A1 bio bi učinkovitiji od energetskog subjekta B1, budući da su troškovi (75 milijuna kuna) energetskog subjekta A1 znatno niži od troškova (150 milijuna kuna) energetskog subjekta B1. Obrnuti slučaj bi se dogodio ukoliko bi se analiza provela u kasnijim godinama. Taj pojednostavljeni primjer naglašava važnost uključivanja dužeg razdoblja u analizu *TOTEX*-a metodom ravnanja prema mjerilu, što s praktične strane komplicira analizu budući da se mora analizirati veći skup podataka. Analiza se dodatno komplicira ukoliko se u obzir uzme različita računovodstvena praksa, što prikazuje tablica 3. Naime, energetski subjekti A1 i A2, odnosno B1 i B2, imaju istu dinamiku investiranja, međutim koriste različita amortizacijska razdoblja, stoga se njihov trošak amortizacije u pojedinoj godini značajno razlikuje (slika 3).

A problem that arises in the total expenditure regulatory approach is connected with investment maturity. *CAPEX*, including depreciation and return on assets, occurs over a series of years. Therefore, when applying the benchmarking method, analysis should take a period of several years into account and should not be performed for expenditures anticipated for only one year. An illustrative example is presented in which *CAPEX* significantly influences the dynamics of the investment, in which only the deprecation cost is shown and not the return on assets (Table 3). If only one year were considered in the analysis, for example the second year of the investment, Energy Entity A1 would be more efficient than Energy Entity B1, since the expenditures (75 million kunas) of Energy Entity A1 are significantly lower than the expenditures (150 million kunas) of Energy Entity B1. The reverse situation would occur if the analysis were performed in later years. This simplified example emphasizes the importance of including a longer period of analysis in the *TOTEX* benchmarking method, which from the practical aspect complicates analysis since it necessitates the analysis of a larger group of data. Analysis is further complicated insofar as various accounting practices are taken into account, as shown in Table 3. Energy Entities A1 and A2, i.e. B1 and B2, have the same dynamics of investment. However, they use different depreciation periods and, therefore, their depreciation costs in an individual year differ significantly (Figure 3).




**Slika 3**
Prikaz godišnjeg troška amortizacije za energetske subjekte čija je razina investiranja kumulativno jednaka, no godišnji trošak amortizacije se razlikuje

**Figure 3**
Annual depreciation costs for energy entities whose levels of investment are cumulatively equal but whose annual depreciation costs differ

Iako su prilikom razmatranja dva različita regulatorna pristupa korišteni poprilično jednostavni primjeri kroz koje su predočene različitosti u pristupima, primjeri odražavaju da se ulaganja trebaju razmatrati kroz duži vremenski rok. Na taj način može se provesti dosljedna regulatorna politika, ne samo u smislu utvrđivanja opravdane razine učinkovitosti, već i u smislu postizanja kontinuiranih

Although two fairly simple examples were used in analyzing the two different regulatory approaches, through which the differences in the approaches were presented, the examples demonstrate that investments must be analyzed over a long period of time. In this manner, it is possible to implement a consistent regulatory policy, not only in the sense of determining the justified level of efficiency but also

reguliranih cijena. Stabilna razina reguliranih cijena bez većih fluktuacija ne može se postići ukoliko su moguće česte promjene cijena usluga kao što je to slučaj s hrvatskim regulatornim okvirom, koji razmatra troškove subjekata koji obavljaju regulirane djelatnosti godinu za godinu. Naime, iako energetski subjekti nastoje, dugoročno gledajući, održavati istu razinu investicija na godišnjoj razini, njihovi troškovi su različiti od godine do godine, a time i razina dozvoljenog prihoda. Pitanje je na koji način će se HERA postaviti prema ovakvom problemu s kojim se susreću regulatorna tijela.

# 4 ULOGA HRVATSKE ENERGETSKE REGULATORNE AGENCIJE U DONOŠENJU PLANOVA RAZVOJA I IZGRADNJE

### 4.1 Zakonodavno rješenje

Hrvatski zakonodavac propisao je Zakonom o tržištu električne energije [8] da HEP OPS i HEP ODS donose planove razvoja i izgradnje za razdoblje od tri godine uz prethodnu suglasnost HERA-e na prijedlog planova. Međutim, zakonodavac ne prepoznaje nadležnost HERA-e u davanju suglasnosti za planove razvoja i izgradnje djelatnosti proizvodnje i opskrbe električnom energijom za tarifne kupce. Primjenjujući ovakvo zakonsko rješenje postavlja se pitanje na koji način će HERA razmatrati investicijske planove subjekata za proizvodnju i opskrbu električne energije i uključiti opravdana ulaganja u regulatornu osnovicu sredstava, budući da na njih temeljem Zakona [8] ne daje suglasnost, a primjenjuje istu metodu regulacije kao kod monopolnih djelatnosti – metoda priznatog troška. Ono što je potrebno napomenuti je da su tarifni sustavi, koje je donijela HERA, a ne zakonodavac, ulogu HERA-e u davanju suglasnosti na planove razvoja i izgradnje definirali kao identičnu za sve djelatnosti, iako to nije u skladu sa zakonskim odredbama. Nadalje, u tekstu svih tarifnih sustava navodi se da HERA daje suglasnost i na planove poslovanja svih djelatnosti iako pojam plan poslovanja Zakon [8] isto tako ne prepoznaje.

Takva razlika nadležnosti između zakonskih odredaba koje je utvrdio Hrvatski sabor i odredaba koje proizlaze iz podzakonskih akata koje je donijelo samo tijelo za sebe, u ovom slučaju HERA, potencira činjenicu da se prije donošenja drugog seta energetskih zakona nije detaljno analizirala uloga i pozicija HERA-e kao regulatornog tijela u energetskom sektoru RH kao niti regulacija energetskih djelatnosti kao disciplina sa svojim značajkama.

in the sense of achieving continuously regulated prices. A stable level of regulated prices without wide fluctuations cannot be achieved if it is possible to change the prices for services frequently, as is the case with the Croatian regulatory framework, which considers the expenditures of the entities performing regulated activities from year to year. Although the energy entities attempt to maintain the same level of investment on the annual level, viewed over the long-term, their costs differ from year to year and therefore the level of allowed revenue also differs. It is a question how the CERA will address this problem.

# 4 THE ROLE OF THE CROATIAN ENERGY REGULATORY AGENCY IN THE ADOPTION OF DEVELOPMENT AND CONSTRUCTION PLANS

### 4.1 Legislative solution

Croatian legislation stipulates that pursuant to the Electricity Market Act [8], the transmission system operator and the distribution system operator shall adopt development and construction plans for periods of three years, pending prior approval of the proposed plans by the CERA. However, the legislation does not recognize the authority of the CERA in issuing approval for the development and construction plans for the activities of the production and supply of electrical energy for tariff customers. Applying such a legal solution, the question arises concerning how the CERA will analyze the investment plans of the entities for the generation and supply of electrical energy and include the justified investment in the regulatory asset base, since according to the Law [8] it does not issue approval and applies the same method of regulation as for monopoly activities – the regulation of the rate of return. It should be mentioned that in the tariff systems which the CERA has adopted, and not the legislator, the roles of the CERA in issuing approval for development and construction plans are defined as identical for all activities, although this is not pursuant to the legal provisions. Furthermore, in the text of all the tariff systems, it is stated that the CERA also issues approval for the business plans of all activities, although the Law does not recognize the concept of a business plan [8].

Such differences in the specified authority between the legal provisions established by the Croatian Parliament and the provisions ensuing from the bylaws that the agency has issued for itself, in this case the CERA, emphasize the fact that the role

Naime, bitno je napomenuti da je HERA osnovana od strane RH kao javna ustanova što znači da joj je temeljem Zakona o ustanovama moguće dodijeliti javne ovlasti, odnosno prenijeti (delegirati) nadležnosti s državnog tijela [13]. Podjeljivanje javnih ovlasti uvijek otvara složeno pitanje smanjuje li se takvim ponašanjem opseg autoritativnog istupa države ili se pak ukupnost autoritativnog postupanja, a to znači i mogućnost uporabe prisile, proširuje. Bez obzira kojoj se konstataciji priklonili, mora se respektirati činjenica da je Zakon o ustanovama propisao da se zakonom ili na temelju zakona donesenom posebnom odlukom može javnoj ustanovi povjeriti da u sklopu djelatnosti radi koje je osnovana općim aktima uređuje određene odnose, da rješava u pojedinim upravnim stvarima o pravima, obvezama i odgovornosti fizičkih i pravnih osoba te da obavlja druge javne ovlasti.

Karakteristično je, također, da je Zakon o sustavu državne uprave, uz svoj temeljni pristup da poslove državne uprave obavljaju tijela državne uprave, propisao da se posebnim zakonom mogu određeni poslovi državne uprave prenijeti i pravnim osobama koje na temelju zakona imaju javne ovlasti [13]. Na temelju ovlasti iz posebnog zakona javne ustanove mogu obavljati najrazličitije poslove iz nadležnosti državnih tijela (posebno tijela državne uprave). Kad se razmotre odredbe Zakona o ustanovama, onda je vidljivo da je Zakon u složenom problemu podjeljivanja javnih ovlasti definirao dvoje:

– pravnu osnovu (izvor) javnih ovlasti – to su zakon, odnosno na temelju zakona donesena odluka predstavničkog tijela jedinica lokalne, područne samouprave,
– sadržaj javnih ovlasti – to je pravo da se općim aktima uređuju određeni odnosi, da se rješava u pojedinačnim upravnim stvarima o pravima, obvezama i odgovornosti određenih subjekata kao i eventualno pravo na obavljanje drugih javnih ovlasti.

Povjeravanje javnih ovlasti javnoj ustanovi znači za nju i određene dužnosti. U djelovanju javne ustanove ostvarivanje njezine posebne uloge (posebnog statusa) realizira se korištenjem javnih ovlasti i izvršavanjem dužnosti koje su joj u svezi s time nametnute. Javna ustanova mora obavljati javne ovlasti samo pod uvjetima, na način i u postupku koji je određen zakonom. Dakle, nemoguće joj je podzakonskim aktima dodjeljivati nadležnosti koje joj zakonski nisu pripisane kao što je to slučaj s pojedinim podzakonskim aktima proizašlim iz energetskih zakona.

and position of the CERA as a regulatory body within the energy sector of the Republic of Croatia and the regulation of energy activities as a discipline with specific characteristics had not been analyzed in detail prior to the adoption of the second set of energy acts. It is important to mention that the CERA was established by the Republic of Croatia as a public institution, which means that pursuant to the Institution Act it can be assigned public authority, i.e. delegated authority from the state entity [13]. The assignment of public authority always raises the complex question of whether the authority of the state is thereby diminished or whether the total authority, which means the option of the use of force, is expanded. In any case, it is necessary to respect the fact that the Institute Act stipulates that according to the law or pursuant to a law adopted by a special decision, a public institution may be entrusted, within the framework of the activities for which it has been established by enactments, to determine specific relationships; to resolve individual administrative issues about the rights, obligations and responsibilities of natural and legal persons; and to exercise other public authority.

It is also characteristic that the State Administrative System Act, in addition to the fundamental approach that the duties of state administration are to be performed by state administrative bodies, stipulates that pursuant to special legislation it is possible for specific duties of the state administration to be transferred to legal persons who have public authority pursuant to the law [13]. Therefore, based upon authorization from special legislation, public institutions are allowed to perform the most varied activities from the areas of the authority of the state bodies (especially state administrative bodies). When the provisions of the Institution Act are examined, it is evident that the Act has defined two issues within the complex problem of the assignment of public authority:

– the legal basis (source) of public authority – i.e. a ruling adopted pursuant to the law by the representative agency of the units of local and regional self-management,
– the content of public authority – i.e. the right to use enactments to determine relationships, to resolve issues concerning the rights, obligations and responsibilities of specific entities in individual administrative matters, as well as the eventual right to exercise other public authority.

The entrusting of public authority to a public institution means that specific duties are entrusted to it. In the operations of a public institution, it exercises its specific role (special status) through the exercise of public authority and the performance of duties that

## 4.2 Kriteriji za davanje suglasnosti na planove razvoja i izgradnje reguliranih energetskih subjekata

Energetski subjekti na koje se doneseni tarifni sustavi odnose nisu još dostavili HERA-i planove poslovanja, razvoja i izgradnje (koliko je poznato autorima) radi davanja suglasnosti. Rok za dostavu planova je 30. studenoga što proizlazi iz odredbi tarifnih sustava. Stoga se u ovom trenutku ne može razmatrati HERA-in odnos prema davanju suglasnosti na planove razvoja i izgradnje te koliko duboko je HERA spremna analizirati kriterije za odabir pojedinih investicija kao i da li će ući u analizu tehničkih rješenja ili će se povesti samo za odlukama energetskih subjekata kao instanci meritornih za definiranje kriterija od HERA-e. Isto tako ne može se razmatrati na koji način će HERA pristupiti utvrđivanju opravdanih, može se reći i učinkovitih, razina pojedinih troškova, te koje investicije će priznati u regulatornoj osnovici sredstava.

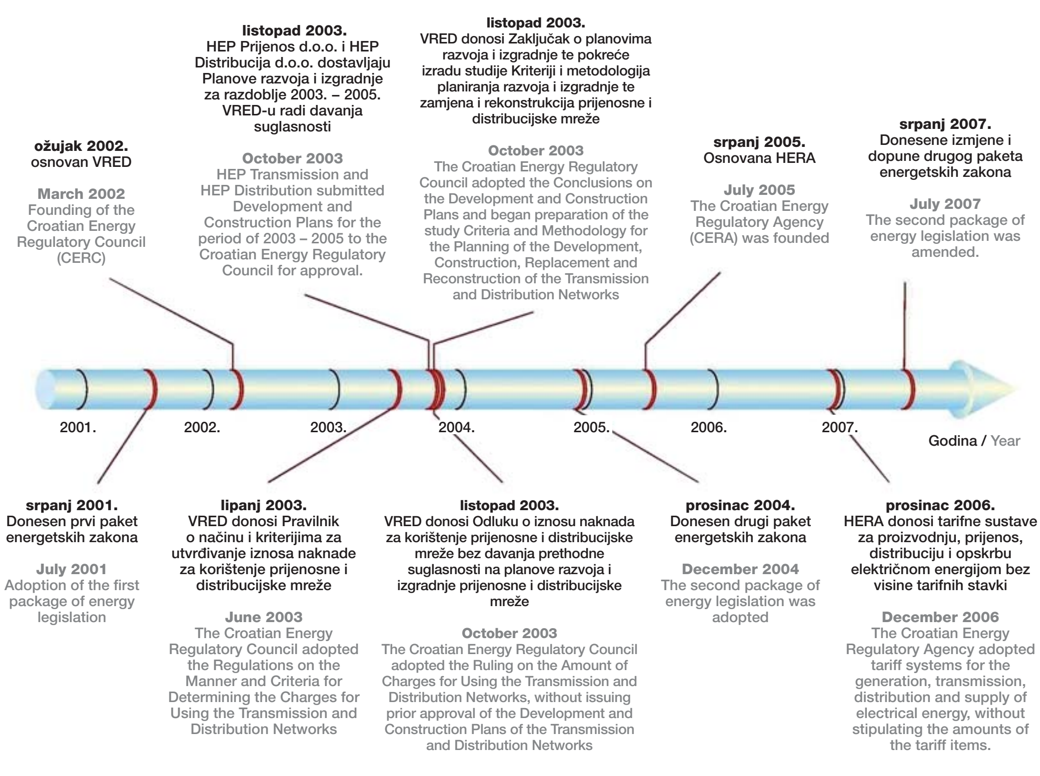
are thereby assigned to it. A public institution must exercise public authority only under the conditions, in such a manner and according to the procedure stipulated for it according to law. Therefore, it is not possible for enactments to assign authorization not stipulated by law, such as in the case of individual enactments resulting from energy legislation.

## 4.2 Criteria for issuing approval for the development and construction plans of entities performing regulated activities

The energy subjects to which the adopted tariff systems refer have still not submitted their plans for operations, development and construction (to the best of the authors' knowledge) to the CERA for approval. The deadline for the submission of the plans is November 30, according to the provisions of the tariff systems. Therefore, at this moment it is not possible to discuss the CERA's attitude toward issuing approval for development and construction plans and how deeply the CERA is prepared to analyze the criteria for choosing individual investments, as well as whether it will enter into analysis of the technical solutions itself or rely solely upon the decisions of the energy entities as sufficiently authoritative for defining its criteria. Similarly, it is not possible to discuss how the CERA will approach the determination of justified, it can be said effective, levels of individual expenditures, and which investments it will recognize in the regulatory asset base.

**Slika 4**
Vremenski tijek donošenja propisa koji su vezani uz ulogu regulatornog tijela (VRED/HERA) u davanju suglasnosti na planove razvoja i izgradnje prijenosne i distribucijske mreže

**Figure 4**
Time line of regulations adopted in connection with the role oh the regulatory body (CERC/CERA) in approving the development and construction plans of the transmission and distribution networks



### 4.2.1 Iskustva Vijeća za regulaciju energetskih djelatnosti

Zakon o tržištu električne energije iz 2001. godine također je definirao da tadašnje regulatorno tijelo, Vijeće za regulaciju energetskih djelatnosti (VRED) [14], daje prethodnu suglasnost na plan razvoja i izgradnje prijenosne i distribucijske mreže. Hrvatski nezavisni operator sustava i tržišta d.o.o. (HNOSIT d.o.o.) i HEP Prijenos d.o.o. u 2003. godini proslijedili su Plan razvoja i izgradnje prijenosne mreže za razdoblje od 2003. do 2005. godine, odnosno HEP Distribucija d.o.o. Plan razvoja i izgradnje distribucijske mreže za razdoblje od 2003. do 2005. godine, VRED-u radi davanja prethodne suglasnosti. Budući da prije toga VRED nije zauzeo stav prema načinu na koji će pristupiti davanju prethodne suglasnosti na planove, VRED je pokrenuo izradu Kriterija i metodologija planiranja razvoja i izgradnje te zamjena i rekonstrukcija prijenosne i distribucijske mreže kojima se nastojalo na razvidan, jasan i dosljedan način utvrditi polazno stajalište regulatornog tijela vis-á-vis strategije razvoja prijenosne i distribucijske mreže kao i kriterija za rekonstrukciju postojećih objekata. Imajući u vidu da rad regulatornog tijela treba počivati na načelima razvidnosti, dosljednosti i stručnosti, VRED je zauzeo stajalište da je energetskom subjektu potrebno jasno definirati što se od njega očekuje tako da i buduća stajališta, odnosno odluke regulatornog tijela budu na svojevrstan način predvidljive. Tim više ukoliko se radi o kapitalno intenzivnim djelatnostima za čija ulaganja su potrebne dugoročnije analize kao i srednjoročan, odnosno dugoročan povrat investicijskih sredstava, koji se ujedno odražava i u iznosu tarifnih stavki.

Ilustrativni primjer VRED-ovog Zaključka iz 2003. godine koje je bilo ishodište za izradu Kriterija i metodologija planiranja razvoja i izgradnje te zamjena i rekonstrukcija prijenosne mreže, odnosno pokretanje dorade dostavljenog Plana razvoja i izgradnje prijenosne mreže za razdoblje od 2003. do 2005. godine, je sljedeći [15]:

I. Plan je potrebno donijeti u skladu sa Strategijom energetskog razvitka i Programom provedbe Strategije energetskog razvitka,

II. Da bi se provela procedura ocjene Plana i davanja suglasnosti na prijedlog Plana propisane člankom 12. stavak 1. Zakona o tržištu električne energije [14] potrebno je ispuniti sljedeće uvjete:

   1) definirati kriterije i metodologiju planiranja razvoja prijenosne mreže kao i metodologiju plana zamjene i rekonstrukcije koje će uključivati i ekonomske kriterije planiranja,

### 4.2.1 Experience of the Croatian Energy Regulatory Council

The Electricity Market Act of 2001 also stipulated that the regulatory body at the time, the Croatian Energy Regulatory Council – CERC (Vijeće za regulaciju energetskih djelatnosti – VRED) [14], would issue prior approval for the development and construction plans of the transmission and distribution networks. In the year 2003, the Croatian Independent System and Market Operator – CISMO (Hrvatski nezavisni operator sustava i tržišta d.o.o. – HNOSIT d.o.o.) and HEP Transmission (HEP Prijenos d.o.o.) forwarded the Development and Construction Plan for the Transmission Network for the Period of 2003 to 2005, and HEP Distribution (HEP Distribucija d.o.o.) forwarded the Development and Construction Plan for the Distribution Network for the Period of 2003 to 2005 to the Croatian Energy Regulatory Council – CERC in order to obtain prior approval. Since the CERC had not previously taken a position regarding the manner in which it would approach the issue of prior approval for plans, it started work on the Criteria and Methodology for Planning the Development, Construction, Replacement and Reconstruction of Transmission and Distribution Networks, by which it attempted to determine the starting position of the regulatory body vis-à-vis the strategic development of the transmission and distribution networks as well as the criteria for the reconstruction of the existing facilities in a transparent, clear and consistent manner. Bearing in mind that the work of the regulatory body should be based upon the principles of transparency, consistency and expertise, the CERC assumed the position that it is necessary to provide a clear definition to the energy entity concerning what is expected of it so that the future positions, i.e. decisions, of the regulatory body would be predictable. This is even more important regarding investments in capital intensive activities, which would require long-term as well as medium-term analysis, i.e. the long-term return of invested assets, as also reflected in the amount of the tariff items.

An illustrative example of the CERC's conclusion from the year 2003, which was the starting point for devising the Criteria and Methodologies for Planning the Development, Construction, Replacement and Reconstruction of the Transmission Network, as well as preparing the final modifications of the submitted Development and Construction Plan for the Transmission Network for the Period from 2003 to 2005, is as follows [15]:

I. The plan must be adopted, pursuant to the Strategy for Energy Development and the Program for the Implementation of the Strategy for Energy Development,

što je u skladu s prijedlogom Mrežnih pravila hrvatskog elektroenergetskog sustava (koja u trenutku donošenja Zaključka nisu bila usvojena), a u kojima se takav kriterij jednoznačno ne definira,

2) planirati izgradnju objekata te zamjenu i rekonstrukcije objekata na način da predviđeni objekti zadovoljavaju definirane kriterije,
3) iskazati troškove HNOSIT-a d.o.o. odvojeno od planova HEP Prijenos d.o.o. te ih procijeniti u skladu s ulogom koju HNOSIT d.o.o. preuzima prema Zakonu o tržištu električne energije,

III. U daljnjim koracima potrebno je započeti sa sljedećim radnjama:

1) definirati zahtjeve koji se postavljaju na prijenosnu mrežu prvenstveno u smislu kvalitete električne energije isporučene izravnim i distributivnim kupcima (frekvencija, napon, raspoloživost mreže), te s obzirom na strateška pitanja razvoja mreže (samodostatnost, tretman susjednih mreža u planiranju, tranziti i uloga mreže u tržištu električne energije, izgradnja novih interkonekcija, modernizacija sustava, kriteriji izgradnje GIS postrojenja i dr.),
2) formirati jedinstvenu bazu podataka nužnu za planiranje razvoja mreže te definirati neke osnovne ulazne podatke bitne kod planiranja poput jediničnih troškova neisporučene električne energije, jediničnih cijena visokonaponske opreme, diskontne stope za potrebe planiranja i dr.,
3) za svaki objekt predviđen za izgradnju ili zamjenu i rekonstrukciju izraditi tehnoekonomski elaborat iz kojeg bi proizašlo da li razmatrani objekt zadovoljava kriterije planiranja definirane Mrežnim pravilima i ostalim pripadnim dokumentima.

Zaključak sličnog karaktera VRED je donio i prilikom ocjene Plana razvoja i izgradnje distribucijske mreže za razdoblje od 2003. do 2005. godine. Na istoj sjednici VRED-a na kojoj je VRED donio navedene Zaključke, VRED je donio Odluku o iznosu naknada za korištenje prijenosne i distribucijske mreže [16] temeljem Zakona o tržištu električne energije iz 2001. godine [14]. Ta Odluka još uvijek je na snazi budući da je tarifni sustavi koje je donijela HERA nisu stavili van snage. Slika 4 prikazuje tijek donošenja relevantnih propisa i odluka koji se odnose na ulogu hrvatskog regulatornog tijela HERA-e, odnosno VRED-a, u donošenju planova razvoja i izgradnje prijenosne i distribucijske mreže.

II. In order to implement the procedures for the evaluation of the Plan and the issue of approval for the proposed Plan stipulated in Article 12, Paragraph 1 of the Electricity Market Act [14], the following prerequisites must be met:

1) to define the criteria and methodology for the planning of the development of the transmission network as well as the methodology for the replacement and reconstruction plan, which will include the economic criteria for planning, pursuant to the proposed Grid Code of the Croatian Electrical Energy System (which at the time of the adoption of the conclusion had still not been adopted), and in which such criteria are not defined unambiguously,
2) to plan the construction of facilities and the replacement and reconstruction of facilities in such a manner that the facilities meet the defined criteria,
3) to present the expenditures of the Croatian Independent System and Market Operator – CISMO (HNOSIT d.o.o.) separately from the plans of HEP Transmission (HEP – Prijenos d.o.o.) and to evaluate them according to the role that the CISMO assumes according to the Electricity Market Act,

III. In subsequent steps, it is necessary to begin the following activities:

1) to define the requirements that are established for the transmission network, primarily in the sense of the quality of the electrical energy to direct customers and customers connected to the distribution network (frequency, voltage and network availability), and regarding the strategic question of network development (self-sufficiency, the treatment of neighboring networks in planning; transit and the role of networks in the electrical energy market, the construction of new interconnections, the modernization of the system, the criteria for the construction of Geographical Information System [GIS] facilities etc.),
2) to establish a unified database necessary for the planning of network development and to define some basic input data required for planning, such as the unit prices of undelivered electrical energy, unit prices of high-voltage equipment, discount rates for the necessary planning etc.,
3) for each facility planned for construction, replacement or reconstruction, to prepare a technical/economic study which would show whether said facility meets the planning criteria defined by the Grid Code and other relevant documents.

#### 4.2.2 Iskustva Hrvatske energetske regulatorne agencije

HERA za sada nije pristupila izradi sličnih kriterija ili stajališta o planovima razvoja i izgradnje HEP OPS-a i HEP ODS-a, niti je utvrdila svoj stav prema dubini analize (prema javno dostupnim informacijama). Nepostojanje unaprijed definiranih kriterija za davanje suglasnosti na planove moglo bi dodatno odgoditi donošenje iznosa tarifnih stavki za pojedine djelatnosti, budući da je davanje suglasnosti na planove preduvjet je za davanje mišljenja na prijedlog iznosa tarifnih stavki koje energetski subjekt dostavlja Ministarstvu gospodarstva, rada i poduzetništva (MINGORP), a MINGORP prosljeđuje HERA-i na mišljenje.

### 4.3 Stavovi Hrvatske energetske regulatorne agencije u rješavanju preduvjeta za primjenu metode priznatih troškova

Iz prethodno iznesene rasprave vezano uz regulatorni pristup gradnje blokova i regulatorni pristup ukupnih troškova vidljivo je da je vrlo značajna uloga regulatornoga tijela u utvrđivanju opravdane razine pojedinih regulatornih parametara. Utvrđena metoda priznatih troškova u donesenim tarifnim sustavima prepoznaje regulatorne parametre koji su ranije analizirani kao što su to – regulatorna osnovica sredstava, amortizacija i stopa povrata u vidu ponderiranog prosječnog troška kapitala. Tarifni sustavi definiraju da mišljenje o priznatim troškovima poslovanja (*OPEX*) i stopi povrata kapitala daje HERA, dok se kapitalni troškovi (*CAPEX*) – regulirana osnovica sredstava, tj. prinos od regulirane imovine i amortizacija utvrđuju na osnovi planova razvoja i izgradnje na koje HERA daje suglasnost. Utvrđena metoda regulacije ne poznaje faktor učinkovitosti kao regulatorni parametar metode.

Osim stava o dubini uplitanja u elemente planova poslovanja, razvoja i izgradnje, HERA bi trebala po mišljenju autora prilikom postupka davanja mišljenja na prijedlog iznosa tarifnih stavki po djelatnostima, između ostalog, svoj stav zauzeti i o sljedećem:

– je li obavljen razvidan i dosljedan nadzor nad razdvajanjem djelatnosti kako u tehničkom i tako i financijskom pogledu,
– opravdanoj razini stope povrata za svaku pojedinu djelatnost,
– koje investicije uključiti u regulatornu osnovicu sredstava, što uključuje i tumačenje pojedinih pojmova iz tarifnih sustava, kao što je npr. pojam nove investicije koje su sufinancirane, a uključene su u regulatornu osnovicu sredstava,
– opravdanoj razini troškova poslovanja (*OPEX*),
– i slično.

The CERC also adopted a conclusion of a similar character in the evaluation of the Development and Construction Plan for the Distribution Network for the Period from 2003 to 2005. At the same CERC session, at which the CERC adopted the previously mentioned conclusions, it also adopted the Decision on Fees for Using the Transmission and Distribution Networks [16], pursuant to the Electricity Market Act of 2001 [14]. This Decision is still in force, since the tariff systems that the CERA adopted are still in force. Figure 4 shows the course of the adoption of the relevant regulations and decisions that refer to the role of the Croatian Energy Regulatory Agency – CERA or the Croatian Energy Regulatory Council – CERC, in the adoption of development and construction plans for the transmission and distribution networks.

#### 4.2.2 Experience of the Croatian Energy Regulatory Agency

For the present, the CERA has not started to develop similar criteria or positions on the development and construction plans of the transmission system operator and the distribution system operator, and has not defined its position toward in-depth analysis. The lack of previously defined criteria for issuing approval for plans could additionally postpone the adoption of the amounts of the tariff items for individual activities, since the issuing of approval for the plans is a prerequisite for issuing an opinion on the proposed amounts of the tariff items which an energy entity submits to the Ministry of the Economy, Labor and Entrepreneurship, and which the Ministry forwards to the CERA for an opinion.

### 4.3 Positions of the Croatian Energy Regulatory Agency in resolving the prerequisites for the application of the rate of return (*RoR*) method

From the previous discussion of the building block regulatory approach and the total expenditure regulatory approach, it is evident that the regulatory body has a highly significant role in the determination of the justified levels of individual regulatory parameters. The rate of return method in the adopted tariff systems recognizes the regulatory parameters that were analyzed previously, such as the regulatory asset base (*RAB*), depreciation and the rate of return regarding the weighted average cost of capital (*WACC*). The tariff systems stipulate that an opinion on the recognized operating expenditure (*OPEX*) and the rate of return on capital shall be issued by the CERA, while the capital expenditure (*CAPEX*) – the regulatory asset base, i.e. the revenue from regulated assets and depreciation shall be determined on the basis of the development and construction plans which shall be approved by the CERA. The established method of regulation does not recognize the efficiency factor as a regulatory parameter.

Jedan od bitnih preduvjeta za mogućnost uvođenja metode regulacije kao što je to metoda priznatih troškova je provođenje razvidnog i dosljednog razdvajanja djelatnosti u punom smislu – od razdvajanja imovine, osoblja do pridjeljivanja potraživanja po kreditima i sl. Jedan od problema je na koji način će HERA pristupiti davanju mišljenja na iznos tarifnih stavki za opskrbu električnom energijom ukoliko se zna da se nisu razdvojile djelatnosti distribucije i opskrbe električnom energijom te da HEP Operator distribucijskog sustava d.o.o. obavlja uz djelatnost distribucije i opskrbu električnom energijom, iako je zakonski rok za razdvajanje istih istekao (1. srpnja 2007. godine) [8].

Isti problem preslikava se i na utvrđivanje opravdane razine *OPEX*-a koji bi se trebao utvrditi na razini koja odražava učinkovitost poslovanja ili barem bi se ta razina tijekom godina trebala približiti učinkovitoj razini koja bi vrijedila da se djelatnost izloži tržišnom natjecanju i rizicima. Između ostalog, postavlja se pitanje što predstavlja *OPEX* u slučaju HEP Opskrbe d.o.o. koja obavlja djelatnost opskrbe samo za povlaštene kupce. Znači, taj trošak tarifni kupci uopće ne bi trebali snositi. Sa stajališta regulatornog tijela koje, uz zaštitu održivog poslovanja energetskog subjekta i omogućavanje nenarušenog tržišnog natjecanja, ima zadatak zaštite kupaca, bilo bi neopravdano priznati taj trošak kroz primjenu metode priznatih troškova i davanja pozitivnog mišljenja na prijedlog iznosa tarifnih stavki koji uključuju trenutačni trošak alociran unutar HEP Grupe na HEP Opskrbu d.o.o.

Nadalje, provedba razvidnog razdvajanja ima utjecaja i na *CAPEX* u svim djelatnostima. Naime, za svaku djelatnost HERA bi trebala utvrditi opravdanu razinu početne regulatorne osnovice sredstava, zatim amortizacijsku politiku i sredstva koja se tijekom regulatornog razdoblja dodjeljuju regulatornoj osnovi sredstva na koju se primjenjuje stopa povrata na kapital. Stopu koja se primjenjuje na srednju vrijednost regulatorne osnovice sredstava utvrđuje HERA na prijedlog energetskog subjekta. Problem koji se ovdje javlja je i utvrđivanje opravdane stope povrata, budući da se radi o djelatnostima koje su po svom karakteru različite – monopolne i tržišne, iz čega proizlaze različiti stupnjevi rizika u poslovanju kao i različiti uvjeti financiranja. Naime, iz opisa metode navedene u tarifnim sustavima nije razvidno koja će se stopa primijeniti i hoće li se ona razlikovati po djelatnostima, iako se radi o istom vertikalno organiziranom poduzeću HEP Grupi. Utvrđivanje stope povrata zahtijeva provođenje detaljnih analiza koje HERA još nije provela. Da bi HERA-in rad dobio na vjerodostojnosti i stručnosti potrebno je da HERA pravodobno, prije donošenje odluka i pod-

In addition to the position on the depth of involvement in the elements of the business, development and construction plans, it is the authors' opinion that the CERA should take a position on the following matters when issuing opinions on the proposed tariff amounts according to activities:

- whether transparent and consistent supervision has been performed over the unbundling of the technical and financial activities,
- the justified level of the rate of return for each individual activity,
- which investments should be included in the regulatory asset base, together with the interpretation of individual concepts from the tariff systems, such as, for example the concept of new investments that are co-financed and included in the regulatory asset base,
- the justified level of operating expenditures (*OPEX*),
- etc.

One of the essential prerequisites for the possible introduction of regulatory methods such as the rate of return method is the transparent and consistent unbundling of activities in the full sense – including the unbundling of assets, personnel, claims on loans etc. One of the problems is how the CERA will approach the issuing of opinions on the amount of tariff items for the supply of electrical energy if it knows that the activities of the distribution and supply of electrical energy have still not been unbundled and that the HEP Distribution System Operator performs the activity of the supply of electrical energy in addition to the activity of the distribution of electrical energy.

The same problem is also reflected in the determination of the justified level of *OPEX*, which should be determined at a level that reflects the efficiency of operations or at least this level during the year should approach a efficiency level that would be valid if the activity were subject to market competition and risks. Thus, among other things, the question is posed what *OPEX* represents in the case of HEP Supply (HEP Opskrba d.o.o.), which only performs the activity of supply for eligible customers. This means that tariff customers should not have to cover this expenditure. From the standpoint of the regulatory body which, in addition to safeguarding the sustainable operations of the energy entity and facilitating inviolable market competition, also has the task of protecting the customers, it would be unjustified to recognize this expenditure through the application of the rate of return method and issue a positive opinion on the proposed amounts of tariff items, which include the current expenditure allocated within the HEP Group for HEP Supply.

zakonskih akata, provede sve nužne analize koje u slučaju utvrđivanja metoda za izračun cijena usluga ponekad (po iskustvima drugih regulatornih tijela) traju i po 18 mjeseci [6].

Osim stope povrata, kod *CAPEX* -a, dilemu predstavlja tumačenje i drugih pojmova koje prepoznaje tarifni sustav, a isti nisu u dovoljnoj mjeri pojašnjeni, npr. vrijednost novih investicija koje su sufinancirane. Pretpostavlja se da ih sufinancira kupac. Trošak investicije koji je financirao kupac ne bi trebao ući u regulatornu osnovicu sredstava niti biti priznat kroz trošak amortizacije energetskog subjekta, budući da bi na taj način kupac plaćao investiciju dva puta – kroz trošak investicije i kroz tarifu. Upitno je na koji način će HERA pristupiti rješavanju problema investicija koje sufinancira kupac.

Navedeni primjeri pitanja na koje HERA mora odgovoriti prilikom davanja mišljenja na prijedlog iznosa tarifa i provođenja regulatorne politike samo su ilustrativni. Primjena ekonomske regulacije seže puno dublje i kompleksnija je od navedenih primjera te zahtijeva detaljne elaboracije i analize. No, i argumentirani stavovi koje HERA treba zauzeti prilikom rješavanja navedenih dilema iz opisanog primjera mogu značajno utjecati na razinu tarifnih stavki pojedinih djelatnosti te na raspodjelu troškova i prihoda između djelatnosti.

Furthermore, transparent division also has an impact on *CAPEX* in all activities. For each activity, the CERA would have to determine the justified level of the initial regulatory asset base, the depreciation policy and the assets that would be allocated to the regulatory asset base during the regulatory period, to which the rate of return on capital would be applied. The rate that is applied to the mean value of the regulatory asset base is determined by the CERA at the proposal of the energy entity. A problem that occurs here is the determination of the justified rate of return, since this concerns activities that differ in nature – monopolistic and market, from which there are different degrees of risks in operations as well as different conditions of financing. From the description of the methods stated in the tariff systems, it is not clear which rate will be applied and whether the rates will differ according to activities, although they concern the same vertically organized enterprise in the HEP Group. Determination of the rate of return requires detailed analysis. In order for the CERA's work to obtain credibility and professionalism, prior to adopting decisions and regulations the CERA must first perform all the necessary analyses in a timely manner, which in the case of the determination of the methods for the calculation of the prices for services sometimes (according to the experiences of other regulatory bodies) requires as long as 18 months [6].

In addition to the rate of return, regarding *CAPEX* there is a dilemma posed by the interpretation of other concepts that the tariff system recognizes, which are not explained to a sufficient extent, such as the value of new investments that are co-financed. It is assumed that they are co-financed by the customer. An investment expenditure that a customer has financed should not enter the regulatory asset base or be recognized as a depreciation expenditure of the energy entity. Otherwise, the customer would have to pay for the investment twice – through the investment expenditure and through the tariff. Therefore, it is a question how the CERA will approach the solution of the problem of investments that are co-financed by the customer.

The cited examples of questions to which the CERA must respond when issuing an opinion on the proposed amounts of tariffs and the implementation of regulatory policies are merely illustrative. The application of economic regulations ranges far deeper, is much more complex than the examples presented and requires more detailed elaboration and analysis. However, the argued positions that the CERA should assume when resolving the cited dilemmas from the example described could significantly affect the level of the tariff items for individual activities and the allocation of expenditures and revenues among the activities.

# 5 ZAKLJUČAK

U utvrđivanju reguliranih cijena primjenjuju se različite metode ekonomske regulacije i to prvenstveno u djelatnostima koje su po svom karakteru monopolne, znači prijenosu i distribuciji električne energije, a ne u djelatnostima proizvodnje i opskrbe koje su po svom karakteru tržišne djelatnosti. Sukladno tome, regulatorno tijelo u većini analiziranih država donosi ili daje suglasnost na planove razvoja i izgradnje monopolnih djelatnosti kao preduvjet za utvrđivanje cijena reguliranih usluga. Zakonska nadležnost regulatornog tijela da donosi ili daje suglasnost na planove razvoja i izgradnje energetskih subjekata u načelu ne daje odgovor koliko duboko je pravo regulatornog tijela da zadire u planove razvoja i izgradnje energetskih subjekata. Stoga se vrlo često u početku uvođenja regulatorne prakse postavlja pitanje koliko meritorno može biti regulatorno tijelo prilikom ulaska u rasprave o pojedinim koncepcijskim rješenjima, odnosno o pojedinim tehničkim pitanjima. Praksa u regulatornim tijelima u EU, odnosno članicama ERRA-e, s dužom regulatornom praksom od HERA-e pokazala je da su koncepcijska rješenja i kriteriji za izgradnju objekata u načelu odluka energetskog subjekta, dok regulatorno tijelo odobrava poslovne planove uključujući financijsko pokrivanje investicijskog plana. Paralelno odobravanju poslovnih planova, regulatorna tijela utvrđuju opravdanu razinu učinkovitosti te razinu kvalitete opskrbe kako se smanjenjem troškova ne bi smanjila i kvaliteta opskrbe.

Regulatorna politika može imati značajan utjecaj na budući prihod energetskog subjekta kroz utvrđivanje regulatorne osnovice sredstava u koju ulaze odobrena ulaganja te kroz utvrđeni faktor učinkovitosti. Odobrena razina ulaganja ima značajan odraz na visinu regulirane cijene koja proizlazi iz primijenjene regulatorne metode. Isto tako, ukoliko se jednom investicija prizna u *CAPEX*-u, a ne realizira se tijekom regulatornog razdoblja za koje je odobrena, nije opravdano opet uključiti je u *CAPEX* u sljedećem regulatornom razdoblju. Ako se radi o kratkom regulatornom razdoblju, kao što je to npr. jedna godina kako je predviđeno tarifnim sustavima koje je donijela HERA, postavlja se pitanje na koji način će regulatorno tijelo pratiti realizaciju investicije i njeno uključivanje u *CAPEX*. Naime, regulatorni pristupi analizirani u ovom članku pokazali su da je prilikom utvrđivanja *CAPEX*-a, odnosno razmatranja učinkovitosti pojedinog energetskog subjekta potrebno analizirati troškove kroz duže vremensko razdoblje. Takvom analizom, odnosno primjenom metoda ravnanja po mjerilu na složenijem skupu podataka, osigurala bi se vjerodostojnost i razvidnost postupanja regu-

# 5 CONCLUSION

In the determination of regulated prices, various methods of economic regulation are applied, primarily to activities that are by their nature monopolistic, i.e. the transmission and distribution of electrical energy, and not to the activities of generation and supply, which are by their nature market activities. Consequently, the regulatory bodies in the majority of the countries analyzed adopt or issue approval for the development and construction plans of monopolistic activities as a prerequisite for the determination of the prices for regulated services. The legal authority of a regulatory body to adopt or issue approval for the development and construction plans of energy entities in principle does not provide an answer to how much of a right the regulatory body has to interfere in the development and construction plans of energy entities. Therefore, the question is very often posed at the beginning of the introduction of regulatory practices concerning how competent a regulatory body can be when entering into a discussion on individual conceptual solutions, i.e. individual technical questions. The practice of the regulatory bodies in the EU or the members of the ERRA, with longer regulatory experience than the CERA, has shown that conceptual solutions and criteria for the construction of facilities are in principle the decision of the energy entity, while the regulatory body approves business plans including the financial coverage of the investment plan. Parallel to approving business plans, the regulatory body determines the justified level of efficiency and the level of the quality of supply, so that a reduction in expenditures does not lead to a reduction in the quality of the supply.

Regulatory policy can have a significant impact on the future revenue of an energy entity through the determination of the regulatory asset base in which approved investments are made and through the determination of the efficiency factor. The approved level of investment is significantly reflected in the amounts of the regulated prices determined from the application of a regulatory method. Similarly, if an investment is recognized in *CAPEX* and is not implemented during the regulatory period for which it has been approved, it is not justified to include it in *CAPEX* again for the subsequent regulatory period. If the regulatory period is short, such as, for example, one year, the question is posed how the regulatory body will monitor the implementation of the investment and its inclusion in *CAPEX*. The regulatory approaches analyzed in this article have demonstrated that when determining *CAPEX*, i.e. considering the efficiency of an individual energy entity, it is necessary to analyze expenditures over a long period of time. With such analysis, i.e. the application of the benchmarking method to a complex

latornog tijela tijekom procesa utvrđivanja cijena reguliranih usluga.

HERA, prilikom donošenja tarifnih sustava i opredjeljenja za metodu regulacije priznatih troškova, nije razmatrala posljedice koje regulatorni pristup može imati na dozvoljeni prihod reguliranih energetskih subjekata. Ujedno nije zauzela jasan i nedvosmislen stav prema nizu pitanja i dilema koje se mogu javiti tijekom postupka davanja suglasnosti na planove razvoja i izgradnje prijenosne i distribucijske mreže kao i tijekom davanja mišljenja na prijedlog energetskih subjekata o iznosu tarifnih stavki. Stoga je postupanje hrvatskog regulatornog tijela u postupku donošenja reguliranih cijena na temelju neke od poznatih metoda ekonomske regulacije još uvijek nedefinirano te nema dosadašnje prakse koja bi se mogla analizirati. Isto tako nepoznata je praksa HERA-e u smislu davanja suglasnosti na planove razvoja i izgradnje HEP OPS-a i HEP ODS-a.

Imajući u vidu dosadašnji tijek uvođenja ekonomske regulacije u Hrvatskoj te argumentaciju iz članka kao i iskustva drugih regulatornih tijela zaključak je autora da se zakonsko rješenje nužno mora mijenjati u više segmenata.

Prvo, da se prilikom definiranja nadležnosti HERA-e definiraju sve njene nadležnosti kroz zakonske odredbe, a ne da se naknadno iste utvrđuju kroz podzakonske akte koje donosi MINGORP ili HERA, kao što je to npr. slučaj s davanjem suglasnosti na planove poslovanja ili planove razvoja i izgradnje energetskog subjekta za proizvodnju i opskrbu električnom energijom.

Drugo, da se uloga HERA-e i primjena neke od poznatih metoda ekonomske regulacije ograniči samo na monopolne djelatnosti za koje su iste i razvijane. Naime, regulacija cijena u klasičnom smislu riječi gubi važnost u djelatnostima koje su po svom karakteru tržišne (u kojima tarifa značajno ovisi o parametrima na koje energetski subjekt ne može utjecati i koje regulatorno tijelo ne može nadzirat, kao što je to npr. cijena goriva) i u kojima regulatorno tijelo ne daje suglasnost na planove, kao što je to slučaj s proizvodnjom i opskrbom električnom energijom.

Treće, zakonsko rješenje sa samo polovično definiranim rokovima pokazalo se kao nedostatno. Naime, predviđen je rok za donošenje tarifnih sustava bez visine tarifnih stavki, a da nije predviđen rok za donošenje iznosa tarifnih stavki.

Posljedica ovakvog slijeda zakonskih rješenja je da su tarifni sustavi doneseni u prosincu 2006. godine, a da nisu prije toga napravljene simulacije

group of data, the credibility and transparency of the behavior of the regulatory body during the process of the determination of the prices for regulated services would be assured.

When adopting tariff systems and deciding upon the method for the regulation of the rate of return, the CERA did not consider the consequences that a regulatory approach can have on the allowed revenue of entities performing regulated activities. It also did not assume a clear and unambiguous position toward a series of questions and dilemmas that can arise during the procedure for the issuing of approval for the development and construction plans of the transmission and distribution networks as well as when issuing an opinion on proposals by energy entities on the amounts of tariff items. Therefore, the procedure by the Croatian Energy Regulatory Agency in the adoption of regulated prices on the basis of some of the recognized methods of economic regulation has still not been defined and there is no practical experience to date that could be analyzed. Similarly, the CERA's practices in the sense of issuing approval for development and construction plans for the transmission system operator and the distribution system operator are also unknown.

Bearing in mind the progress thus far in the introduction of economic regulation in the Republic of Croatia and the argumentation from the article, as well as the experiences of other regulatory bodies, it is the authors' conclusion that several segments of the legislative solution in the Republic of Croatia must be changed.

First, all of the CERA's authorities should be defined through legal provisions instead of determining them retrospectively through regulations issued by the Ministry of the Economy, Labor and Entrepreneurship or the CERA, such as, for example, the case of issuing approval for the business plans or the development and construction plans of an energy entity for the generation and supply of electrical energy.

Second, the role of the CERA and the application of some of the recognized methods of economic regulation should be limited to the monopolistic activities for which they were developed. Price regulation in the classical sense has diminished significance in activities with a market character (in which the tariff significantly depends upon parameters which the energy entity cannot influence and which the regulatory body cannot supervise, such as, for example, the price of fuel) and for which the regulatory body does not issue approval for plans, such as in the case of the generation and supply of electrical energy.

prihvaćene metode priznatih troškova s ulaznim podacima od HERA-e odobrenih planova razvoja i izgradnje reguliranih energetskih subjekata. Takva simulacija iznosa tarifnih stavki bi na razvidan način prikazala HERA-in stav prema priznavanju razine *OPEX*-a i *CAPEX*-a.

Third, a legal solution with only partially defined deadlines has proven to be insufficient. The deadline has been set for the adoption of tariff systems without the stipulation of the amounts of the tariff items, and the deadline for the adoption of the tariff items has not been set.

As a consequence of such a sequence of legislative solutions, the tariff systems were adopted in December 2006 without prior simulations based upon the accepted rate of return method and the input data came from development and construction plans of the entities performing regulated activities which the CERA had not previously approved. Such simulations of the amounts of the tariff items would present the CERA's position toward the recognized levels of *OPEX* and *CAPEX* in a transparent manner.

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Uredništvo primilo rukopis:
2007-08-14

Prihvaćeno:
2007-09-14

Manuscript received on:
2007–08–14

Accepted on:
2007–09–14

# ULOGA REGULATORNOG TIJELA U DONOŠENJU TARIFNIH SUSTAVA: OKRUGLI STOL – PRIKAZ I ZAKLJUČCI

# THE ROLE OF THE REGULATORY AGENCY IN THE ADOPTION OF TARIFF SYSTEMS: ROUND TABLE DISCUSSION – REPORT AND CONCLUSION

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Krajem 2006. godine Hrvatska energetska regulatorna agencija donijela je metodologije za izračun tarifa za djelatnosti proizvodnje, prijenosa, distribucije i opskrbe električnom energijom, koje su do sada bile komponente jedinstvene tarife za integrirani sustav djelatnosti proizvodnje, prijenosa, distribucije i opskrbe električnom energijom. Sukladno zakonskoj obvezi razdvajanja navedenih djelatnosti, izraženih i kroz pristup spomenutim metodologijama tarifnih sustava, u tijeku su poslovi vezani uz izračun i donošenje tarifnih stavki za navedene energetske djelatnosti. Primjenom spomenutih metodologija, odnosno donošenjem i stupanjem na snagu novih tarifnih stavki elektroenergetski sektor i elektroenergetsko gospodarstvo Republike Hrvatske ući će u probno regulatorno razdoblje. Stoga je i za regulatorno tijelo, za predstavnike reguliranih djelatnosti, jednako tako i za stručnu javnost od velike važnosti i pomoći bilo raspraviti neka pitanja i dileme iz predmetne problematike, i to upravo na skupu s predstavnicima raznih zainteresiranih strana.

In late 2006, the Croatian Energy Regulatory Agency adopted methodologies for the calculation of tariffs for the activities of the generation, transmission, distribution and supply of electricity, which until now have been components of a single tariff for an integrated system of the activities of the generation, transmission, distribution and supply of electricity. Pursuant to the legal obligations to separate these activities, as also expressed through the approach of the cited methodologies of the tariff systems, activities are in progress in reference to the calculation and adoption of tariff items for the aforementioned fundamental energy activities. With the application of the cited methodologies, i.e. the adoption and coming into force of the new tariff systems of the electricity sector and the electricity sector of the Republic of Croatia, a new trial regulatory period will be entered. Therefore, for the regulatory agency, representatives of the regulated entities, and professional public, discussion of several questions and dilemmas from this area at a meeting among representatives of various interested parties was considered to be of great importance and benefit.

Ključne riječi: energetsko regulatorno tijelo, ekonomska regulacija, metoda priznatih troškova, metodologija tarifnog sustava, regulacija stopom povrata

Key words: economic regulation, energy regulatory agency, method of recognized costs, regulation of the rate of return, tariff system methodology

# 1 UVOD

Na inicijativu SO C5 – Tržište električnom energijom i regulacija, IO HRO CIGRÉ, u Zagrebu je 15. svibnja 2007. godine održan Okrugli stol – Uloga regulatornog tijela u donošenju tarifnih sustava.

Okrugli stol organiziran je sa svrhom i ciljem da predstavnici regulatornih tijela i predstavnici reguliranih subjekata uz prisutnost stručne javnosti izlože svoja iskustva i poglede, odnosno rasprave problem uloge i postupanja regulatornog tijela te sadržaja ekonomske regulacije kada su u pitanju tarifni sustavi za proizvodnju, prijenos, distribuciju i opskrbu električnom energijom. Naravno, postoji bitna razlika između, s jedne strane proizvodnje i opskrbe električnom energijom kao primarno tržišnih djelatnosti, dakle djelatnosti izloženih konkurenciji, i s druge strane infrastrukturnih prirodnih monopolnih djelatnosti prijenosa i distribucije električne energije, koji su u pravilu regulirane djelatnosti. Zakonodavni i regulatorni okvir u kojem postoji jasno izražena obveza javne usluge opskrbe tarifnih kupaca taj kontekst može djelomično izmijeniti na način da energetske djelatnosti proizvodnje i opskrbe električnom energijom i nadalje ostaju predmetom ekonomske regulacije i nadzora energetskog regulatornog tijela. Tako su u ovom slučaju sve četiri navedene usluge stavljene u kontekst općeg ekonomskog (gospodarskog) interesa i povjerena jednom poduzeću, da bi se osigurala sigurna, redovita i kvalitetna opskrba energijom po razumnim cijenama, vodeći računa o zaštiti okoliša. U svakom slučaju, problematika odabira pristupa i utvrđivanja metodologije ekonomske regulacije i donošenja odgovarajućih tarifnih sustava za svaku od navedenih energetskih djelatnosti, koje su ranije bile uključene u integrirani tarifni sustav, i na koje se sada trebaju primijeniti zasebni tarifni sustavi, stvara jedan potpuno novi problem koji je uz to praćen problemom efikasnog odvajanja energetskih djelatnosti. Dakako, sustavi i regulatorna tijela drugih zemalja bili su suočeni i suočavaju se sa sličnim pitanjima i problemima. Stoga je bilo važno raspraviti neka pitanja i dileme iz predmetne problematike s predstavnicima raznih zainteresiranih strana, a poglavito je bilo važno čuti iskustva i stavove relevantnih eksperata iz europskih regulatornih tijela i zemalja s višegodišnjim iskustvom u ekonomskoj regulaciji, bilo da se radi o dugogodišnjim članicama EU, ili zemljama koje su tek nedavno postale članice EU.

# 1 INTRODUCTION

At the initiative of SC C5 – Electricity Markets and Regulation, the Croatian National Committee of CIGRÉ, the Round Table Discussion on the Role of the Regulatory Agency in the Adoption of Tariff Systems was held in Zagreb on May 15, 2007.

The Round Table Discussion was organized with the purpose and goal of providing the opportunity for representatives of the regulatory bodies and the regulated entities to present their experiences and views in the presence of the professional public, i.e. discuss the problem of the role and approach of the regulatory agency and the content of economic regulation regarding the question of the tariff systems for the generation, transmission, distribution and supply of electricity. Naturally, there are significant differences between the generation and supply of electricity as primary market activities, i.e. activities subject to competition on the one hand, and on the other hand the infrastructural natural monopolistic activities of the transmission and distribution of electricity, which as a rule are regulated activities. The legislative and regulatory framework in which there are clearly expressed public service obligation supplying tariff customers can partially alter this context in that the energy activities of the generation and supply of electricity continue to remain subject to economic regulation and supervision by the energy regulatory agency. All four of the stated services are considered to be of general economic interest and entrusted to a single enterprise in order to assure a reliable, regular and quality energy supply at reasonable prices, while taking environmental protection into account. In any case, the problems of selecting an approach, determining a methodology for economic regulation and adopting the suitable tariff systems for each of the cited energy activities that were previously included within an integrated tariff system, for which it is now necessary to apply separate tariff systems, create a completely new problem which is accompanied by the problem of the effective separation of energy activities. Certainly, the systems and regulatory agencies of other countries have been confronted with similar questions and problems. Therefore, it was important to discuss certain questions and dilemmas regarding this topic with representatives of various interested parties and it was especially important to hear about the experiences and positions of relevant experts from the European regulatory agencies and countries with many years of experience in economic regulation, whether longstanding members of the European Union or countries that have only recently become members of the EU.

U radu Okruglog stola po pozivu su uz prezentacije i predavanja, te kroz diskusije različitih uloga i nadležnosti regulatornih tijela, ali i praktičnih pristupa regulaciji i problemu donošenja tarifnih sustava, sudjelovali predstavnici regulatornih tijela Francuske, Austrije, Slovenije, Mađarske i Hrvatske, te predstavnici Hrvatske elektroprivrede d.d., odnosno predstavnici energetskih subjekta u Republici Hrvatskoj za koje se donose i primjenjuju odgovarajući tarifni sustavi. Okrugli stol pobudio je veliki interes stručne javnosti i intenzivnu diskusiju problema i sadržaja uloge regulatornog tijela kada su u pitanju regulatorni pristupi i metode ekonomske regulacije energetskih djelatnosti, dakako onih energetskih djelatnosti koji imaju monopolne pozicije ili kojima su pridijeljene obveze javnih usluga. Interes za teme metodologija tarifnih sustava, strukture, utjecajnih parametara, podloga i dokaza za utvrđivanje razine tarifnih stavki i inače pobuđuju veliki interes, što se očitovalo i na ovom Okruglom stolu.

In the Round Table Discussion, in addition to invited presentations, lectures and the discussion of the various roles and authorities of regulatory agencies, as well as practical approaches to regulation and the adoption of tariff systems, representatives of the regulatory agencies of France, Austria, Slovenia, Hungary and Croatia as well as representatives of Hrvatska elektroprivreda d.d., i.e. representatives of the energy entities in the Republic of Croatia who adopt and apply the corresponding tariff systems, also participated. The Round Table Discussion aroused great interest among the professional public and provoked intense discussion on the problem and content of the role of the regulatory agency regarding regulatory approaches and methods for the economic regulation of energy activities, i.e. those energy activities that have a monopoly position or to whom the public service obligation has been assigned. The topics of the methodologies of the tariff systems, the structure, influential parameters, basis and evidence for the determination of various tariff items attract great interest generally, which was also apparent at this Round Table Discussion.

## 2 OSNOVNI ZAKONODAVNI OKVIR EU ZA USPOSTAVU TRŽIŠTA ELEKTRIČNE ENERGIJE I SADRŽAJ REGULACIJE

Ključni akti Europske komisije koji definiraju opći okvir osnivanja i rada energetskih regulatornih tijela, odnosno utvrđuju opće smjernice i standarde organizacije energetskog tržišta i nadležnosti tih tijela u svezi električne energije su:

- Direktiva 2003/54/EZ Europskog parlamenta i Vijeća ministara o općim pravilima za unutrašnje tržište električne energije i prestanku važenja Direktive 96/02/EZ, koja utvrđuje opća pravila za proizvodnju, prijenos, distribuciju i opskrbu električnom energijom, te definira pravila o organizaciji i funkcioniranju elektroenergetskog sektora, pristupa tržištu, kriterije i postupke koji se primjenjuju za objavu nadmetanja i davanje odobrenja i upravljanje sustavima,
- Direktiva 2003/55/EZ Europskog parlamenta i Vijeća o zajedničkim pravilima unutarnjeg tržišta prirodnog plina i ukidanju Direktive 98/30/EZ, koja utvrđuje zajednička pravila za prijenos, distribuciju, opskrbu i skladištenje prirodnog plina, LNG-a i druge tipove plinova koji se mogu tehnički i sigurno ubacivati i transportirati kroz sustav za prirodni plin, te definira pravila o organizaciji i funkcioniranju sektora, pristupa tržištu, kriterije i postupke

## 2 THE BASIC LEGISLATIVE FRAMEWORK OF THE EUROPEAN UNION FOR THE ESTABLISHMENT OF AN ELECTRICITY MARKET AND THE CONTENT OF REGULATION

The key acts of the European Commission that define the general framework for the establishment and activity of energy regulatory agencies, i.e. determine the general guidelines and standards for the organization of the energy market and the authorities of these bodies in connection with electricity, are as follows:

- Directive 2003/54/EC of the European Parliament and of the Council of Ministers on Common Rules for the Internal Market in Electricity and Repealing Directive 96/02/EC, that determines the general rules for the generation, transmission, distribution and supply of electricity and defines the rules on the organization and function of the electricity sector, market approach, the criteria and processes that are applied for announcing tendering procedures, issuing authorizations and managing systems,
- Directive 2003/55/EC of the European Parliament and of the Council Concerning Common Rules for the Internal Market in Natural Gas and Repealing Directive 98/30/EC, which determines the common rules for the transmission, distribution, supply and storage of natural gas, liquefied

koji se primjenjuju na davanje odobrenja i rad sustava,

– Uredba 1228/2003/EZ Europskog parlamenta i Vijeća o uvjetima pristupa mreži za prekograničnu razmjenu električne energije, te
– Uredba 1775/2005/EZ o uvjetima pristupa transportnim mrežama za prirodni plin.

Unutar tog općeg zakonodavnog okvira regulatornom tijelu mogu se dodijeliti različite nadležnosti i odgovornosti, odnosno poslovi. Na Okruglom stolu prezentacijama i raspravom primarno su bile obuhvaćene nadležnosti i uloga regulatornog tijela u pogledu donošenja metodologija tarifnih sustava i/ili određivanja tarifa/naknada za energetske usluge, odnosno krajnje kupce. Neposredno u svezi s tim prezentirani su i raspravljeni i mogući pristupi reguliranju monopola ili javnih usluga (cijena korištenja mreže, uvjeta pristupa mrežama, pravila za vođenje sustava, uvjeta osiguranja stabilnosti i pouzdanosti sustava, pravila i uvjeta osiguranja pomoćnih usluga sustava). Širom raspravom bile su obuhvaćene i ostale nadležnosti i poslovi koji se u pravilu dodjeljuju regulatornom tijelu, kao što su nadzor standarda kvalitete i izvedbe, kreiranje i provođenje općih uvjeta, propisa i standarda, reguliranje ulaska energetskih subjekata u sektor (dozvole, povlašteni statusi, priključenja, nova izgradnja) i nadzor nad tržištem, izvještavanje, savjetovanje vlade, ministarstava, javnosti, rješavanje žalbi na rad operatora sustava i rješavanje žalbi i sporova kupaca.

Na Okruglom stolu jasno je pokazano da je unutar tog jednog općeg zakonodavnog okvira svaka zemlja članica EU razvila i uspostavila vlastiti zakonodavni i regulatorni okvir za tržište električne energije i rad nacionalnog regulatornog tijela, temeljeći rješenja i praksu na važećem osnovnom nacionalnom pravnom i zakonodavnom sustavu. Opće je pravilo, a isto je više puta i u svim slučajevima ponovljeno na gotovo istovjetan način od strane predstavnika regulatornih tijela Francuske, Austrije, Slovenije, Mađarske i Hrvatske, sudionika Okruglog stola, da je cilj svake zemlje uspostaviti neovisno i efikasno nacionalno regulatorno tijelo koje će stvoriti uvjete i nadzirati razvoj i uspostavu razvidnog, efikasnog i nepristranog tržišta električne energije i plina na dobrobit svih sudionika tih tržišta i krajnjih korisnika. Preduvjeti razvidnog, efikasnog i nepristranog tržišta električne energije i plina su osiguranje i provedba razvidnog i nediskriminirajućeg pristupa energetskim mrežama po unaprijed poznatim, reguliranim uvjetima, neovisan i nepristran rad operatora energetskih sustava, razvidno i nepristrano rješavanje sporova i prigovora na pristupe mrežama i rad operatora mrežnih sustava, efikasna provedba i garancije računovodstvenog i upravljačkog

natural gas (LNG) and other types of gases that can technically and safely be injected into and transported through the natural gas system, and defines the rules on the organization and function of the sector, market access, criteria and procedures that are applicable to the granting of authorizations and the operation of the system,

– Regulation 1228/2003/EC of the European Parliament and of the Council on Conditions for Access to the Network for Cross-Border Exchanges in Electricity, and
– Regulation 1775/2005/EC of the European Parliament and of the Council on Conditions for Access to the Natural Gas Transmission Networks.

Within this general legislative framework, various authorizations and responsibilities, i.e. tasks can be assigned to a regulatory agency. At the Round Table, the presentations and discussions were primarily about the authorities and roles of the regulatory agency regarding the adoption of methodologies for tariff systems and/or determining tariffs/charges for energy services, i.e. the final customers. In connection with this, potential approaches to the regulation of monopolies or public services were presented and discussed (the cost of network use, conditions for network access, rules for system management, conditions for assuring the stability and reliability of a system, and rules and conditions for securing auxiliary system services). Broader discussions included other authorities and tasks that as a rule are assigned to the regulatory body, such as the supervision of the standards for quality and implementation, the creation and implementation of general conditions, regulations and standards; regulation of the entry of energy entities into the sector (permits, privileged status, connections and new construction) and supervision over the market, reporting; advising the government, ministries and public; the settling of complaints regarding the work of the system operator, and customer complaints and disputes.

At the Round Table Discussion, it was clearly demonstrated that within this general legislative framework, each Member Country of the EU has developed and established its own legislative and regulatory framework for the electricity market and the work of the national regulatory agency, based upon the solutions and practice of the prevailing basic national legal and legislative system. As a general rule, which was repeated in all cases in a nearly identical manner in the presentations by the representatives of the regulatory agencies of France, Austria, Slovenia, Hungary and Croatia, i.e. the Round Table participants, the goal of every country is to establish an independent and efficient national regulatory agency that will create the conditions, supervise the development and establish transparent, efficient and nondiscriminatory electricity and gas markets for the benefit of all the

razdvajanja energetskih djelatnosti, sprječavanje međusobnih subvencioniranja reguliranih i nereguliranih djelatnosti unutar vertikalno ili horizontalno integriranih sustava, efikasan sustav prekograničnih razmjena, razvoj i uspostava efikasnih tržišnih mehanizama i slobodna tržišna utakmica itd.

S druge strane, činjenice i pojavnost su da regulatorna tijela u različitim zemljama imaju različite pozicije u odnosu na državna tijela i institucije, prvenstveno odgovarajuće vlade i ministarstva, te različite uloge i nadležnosti. U nekim zemljama regulatorna tijela su organizacijska jedinica ili dio ministarstva ili pod nadzorom ministarstva ili vlade. U drugim zemljama su ili značajno ili u potpunosti neovisna tijela. U nekim zemljama regulatorna tijela imaju nadležnost i obvezu nadzora provedbe podzakonskih akata, donošenja metodologija tarifnih sustava, davanja odobrenja na planove razvoja i planove investiranja reguliranih subjekata, nadzora provedbe ili primjene tarifnih sustava i tarifa, nadzora financijskog poslovanja, nadzora provedbe računovodstvenog i upravljačkog razdvajanja, nadzora kvalitete energetskih usluga, davanja odgovarajućih mišljenja i savjetovanja ministarstava i vlada o cijenama, tarifama, pitanjima uspostave energetskog tržišta i sl. U drugim zemljama nacionalna regulatorna tijela imaju jaču ulogu i nadležnosti, koje uključuju donošenje odgovarajućih podzakonskih akata, ali i poduzimanje odgovarajućih mjera, utvrđivanje tarifa i uvjeta pristupa mrežama, rješavanje sporova u svezi s pristupom mrežama i uvjetima korištenja mreža, rješavanje prigovora i žalbi na rad operatora mrežnih sustava, rješavanje prigovora i žalbi krajnjih kupaca i slično. Nisu zanemarivi i sustavi mjera i sankcija koje nekim regulatornim tijelima stoje na raspolaganju da bi osnažili svoje djelovanje i odluke.

Kada su u pitanju nadležnosti za definiranje i donošenje metodologija ekonomske regulacije, odnosno izbor, definiranje i donošenje osnovnog regulacijskog pristupa, metodologije tarifnog sustava i samih tarifa, uloge regulatornih tijela se razlikuju. Opet, u nekim zemljama regulatorna tijela imaju ključnu ulogu u svim segmentima procesa od definiranja metode regulacije i metodologije tarifnog sustava, nadzora poslovanja i revizije financijskih pokazatelja i izvješća energetskih subjekata, dubinske revizije i odobravanja troškova, definiranja i odobravanja ključnih regulacijskih i makroekonomskih parametara, primjene mehanizama javnog prezentiranja i očitovanja javnosti, odnosno korisnika i kupaca o iznosima tarifnih stavki itd. U drugim zemljama regulatornim tijelima dane su u nadležnost i obveze samo neka od navedenih prava, poslova i obveza. Najčešći

participants of these markets and the final customers. The prerequisites for transparent, efficient and nondiscriminatory electricity and gas markets are the assurance and implementation of transparent and nondiscriminatory access to the energy networks according to previously specified regulatory conditions, the independent and nondiscriminatory work of the energy system operators, the transparent and nondiscriminatory resolution of disputes and complaints regarding network access and the work of the network system operators, the efficient implementation and guarantee of the accounting and managerial unbundling of energy activities, the prevention of cross subsidies among regulated and unregulated activities within vertically or horizontally integrated systems, an effective system for cross-border exchanges, the development and establishment of efficient market mechanisms and free market competition etc.

Otherwise, the regulatory agencies in various countries have differing positions in relation to the state agencies and institutions, primarily the corresponding governments and ministries, and various roles and authorities. In some countries, the regulatory agencies are organizational units, parts of a ministry or under the supervision of a ministry or the government. In other countries, they are either considerably or entirely independent bodies. In some countries, the regulatory bodies have the authority and responsibility of supervising the implementation of bylaws, the adoption of the methodologies of the tariff systems, granting approval for the development and investment plans of the regulated entities, supervision over the implementation or application of tariff systems and tariffs, supervision over financial operations, supervision over the implementation of accounting and managerial unbundling, supervision over the quality of energy services, issuing suitable opinions and advising ministries and the government regarding prices, tariffs, questions regarding the establishment of the energy market etc. In other countries, the national regulatory agency has a strong role and powerful authority, including the adoption of suitable bylaws but also the undertaking of suitable measures for the determination of tariffs and conditions for network access, the settlement of disputes in connection with network access and conditions for network use, the settlement of complaints regarding the work of the network system operator, the settlement of complaints from the final customers etc. The system of measures and penalties that some regulatory agencies have at their disposal to enforce their activity and decisions is not insignificant.

When authorities are in question for the definition and adoption of methodologies for economic regulation, i.e. the selection, definition and adoption of the basic regulatory approach, methodologies of the tariff system and tariffs themselves, the roles of the

je slučaj da regulatorno tijelo ima obvezu i odgovornost za donošenje odgovarajuće metodologije tarifnih sustava, te nadzora poslovanja i troškova reguliranih subjekata. Regulatorna tijela u nekim zemljama daju mišljenja odgovarajućim ministarstvima i vladama u pogledu visine tarifnih stavki, u drugim zemljama imaju nadležnost utvrđivanja, odnosno reguliranja tarifnih stavki, što je u pravilu i cilj njihova osnivanja.

Konačno, nužno je ukazati i na treći aspekt ili razinu mogućih nadležnosti i odgovornosti regulatornih tijela. Tu treću razinu čine pristupi pojedinim segmentima ili problemima ekonomske regulacije kao što su problemi kriterija za pridjeljivanje i priznavanje razine operativnih troškova poslovanja, odobravanja i priznavanja investicija u nove objekte, postrojenja i instalacije, troškova kapitala, odnosno amortizacije i povrata na uložena sredstva, utvrđivanja odgovarajuće regulatorne baze i stope povrata na reguliranu imovinu, priznavanja odgovarajućih inflatornih utjecaja na troškove i tarife, utvrđivanja i priznavanja i drugih korektivnih faktora na troškove i tarife, te konačno i postupanja u slučaju viškova i manjkova prihoda na karaju regulacijskog perioda. Posebno je pitanje odnosa i postupanja prema kategorijama prihoda koji imaju obilježja profita. Naravno, za ovaj treći regulacijski aspekt vezana su i pitanja, odnosno problemi koliko dug regulacijski period ustanoviti, kada primijeniti jednostavne, a kada početi primjenjivati složene metode ekonomske regulacije.

Često je prisutna i dilema kada uvesti poticajnu regulaciju, kako složene regulacijske pristupe i mehanizme učiniti razumljivim, razvidnim i prihvatljivim svim sudionicima, naročito energetskim subjektima koji iste trebaju primijeniti i korisnike ili kupce na koje se isti odnose, i končano, kako osigurati da ti mehanizmi u sukcesivnom slijedu rezultiraju stabilnom i efikasnom strukturom tarifa i sl. Za mrežne infrastrukturne sustave i prirodne monopolne energetske djelatnosti uz navedene treba dodati i pitanja odgovornosti i načina osiguravanja pomoćnih usluga sustava, pokriće troškova gubitaka, odgovornosti za pravovremen i dostatan razvoj i izgradnju sustava, te izgradnju dostatnih prekograničnih kapaciteta. Dodatno, operatori prijenosnog i distributivnog sustava imaju i odgovornosti u pogledu uključivanja i osiguravanja uvjeta za rad postrojenja koja koriste obnovljive izvore energije.

regulatory agencies differ. In some countries, the regulatory bodies have a crucial role in all the segments of the process, including the definition of the method for regulation and the methodology of the tariff system, supervision over operations and the auditing of financial indices and reports of energy entities, in-depth auditing and approval of expenditures, the definition and approval of crucial regulatory and macroeconomic parameters, the application of mechanisms for presentations and statements to the public, i.e. users and customers, about the amounts of tariff items etc. In other countries, the regulatory agencies are granted the authority and responsibility for only some of the stated rights, activities and responsibilities. The most frequent case is that a regulatory agency has the obligation and responsibility for the adoption of a suitable tariff system methodology, together with the supervision of the operations and expenditures of the regulated entities. The regulatory bodies in some countries issue an opinion to the corresponding ministries and governments regarding the amounts of tariff items, and in other countries they have the authority to determine or regulate the tariff items, which as a rule is the purpose for their establishment.

Finally, it is necessary to draw attention to the third aspect or level of the potential authorities and responsibilities of regulatory bodies. This third level consists of approaches to individual segments or problems of economic regulation, such as the problems of the criteria for the allocation and recognition of the level of operational costs, approval and recognition of investments in new facilities, plants and installations; capital costs, i.e. depreciation and investment return, determination of the suitable regulatory basis and rate of return on regulated property, recognition of the impact of inflation on costs and tariffs; the determination and recognition of other corrective factors on costs and tariffs, and finally the procedure in the event of revenue surpluses and deficits at the end of the regulatory period. A particular question refers to the attitude and procedure toward the categories of revenue that have recorded profits. Naturally, questions are connected with this third regulatory aspect, i.e. problems regarding how long a regulatory period should be established, when simple methods should be applied and when it is necessary to begin to apply complex methods of economic regulation.

There is often the issue of when to introduce incentive regulation, how to make complex regulatory approaches and mechanisms understandable, transparent and acceptable to all the participants, especially energy entities who must apply them and the users or customers to which they refer, how to assure that these mechanisms successively result in a stable and efficient tariff structure etc. For network infrastructure systems and naturally monopolistic

## 3 RESTRUKTURIRANJE ELEKTROENERGETSKOG SEKTORA, REGULACIJA I TARIFNI SUSTAVI U REPUBLICI HRVATSKOJ

U uvodnom dijelu Okruglog stola detaljno je izložen kontekst energetskog zakonodavnog okvira i procesa restrukturiranja elektroenergetskog sektora, odnosno otvaranja tržišta električne energije i razvoja i uspostavljanja novog regulatornog okvira u Republici Hrvatskoj [1], [2] i [3]. U tom kontekstu i okružju donesene su i objavljene metodologije tarifnih sustava, a tek treba utvrditi odgovarajuće stavke za prijenos i distribuciju električne energije te proizvodnju i opskrbu električnom energijom s izuzetkom za povlaštene kupce.

Naime, temeljem vrijedećih zakona Hrvatska energetska regulatorna agencija (u daljnjem tekstu: Agencija) ima obvezu i odgovornost, nakon pribavljenog mišljenja energetskih subjekata za obavljanje čijih djelatnosti se primjenjuje tarifni sustav i Ministarstva gospodarstva, rada i poduzetništva (u daljnjem tekstu: Ministarstvo), u sektoru električne energije donijeti metodologije tarifnih sustava, odnosno tarifne sustave bez visine tarifnih stavki, i to za: 1) proizvodnju električne energije, s iznimkom za povlaštene kupce, 2) opskrbu električnom energijom, s iznimkom povlaštenih kupaca, 3) prijenos električne energije, 4) distribuciju električne energije, 5) utvrđivanje naknade za priključak na prijenosnu i distribucijsku mrežu, te povećanje priključne snage, 6) pružanje usluga uravnoteženja električne energije u elektroenergetskom sustavu.

Prethodno navedene metodologije moraju omogućavati ulaganja potrebna za razvoj mreže i ostale zahtjeve sukladno postojećim zakonima.

Temeljem vrijedećih zakona energetski subjekt za obavljanje čijih djelatnosti se primjenjuje tarifni sustav podnosi prijedlog visine tarifnih stavki Ministarstvu, koje nakon pribavljenog mišljenja Agencije predlaže iznose tarifnih stavki Vladi Republike Hrvatske. Vlada Republike Hrvatske utvrđuje visinu tarifnih stavki. Agencija provodi nadzor primjene tarifnih stavki i svih ostalih naknada.

Na Okruglom stolu detaljno je izložen kontekst utvrđivanja i sadržaja metodologija tarifnih sustava za proizvodnju električne energije, s iznimkom za povlaštene kupce, opskrbu električnom energijom, s iznimkom povlaštenih kupaca, prijenos električne energije i distribuciju električne energije. U nastavku slijedi prikaz do sada vrijedećeg

energy activities, is also necessary to add questions of responsibility and the manner of assuring auxiliary services for the system, covering losses, responsibility for the timely and suitable development and construction of the system, and the construction of adequate cross-border capacities. Additionally, the transmission and distribution system operators have responsibilities in respect to the inclusion and assurance of the conditions for the operation of the plants that use renewable energy sources.

## 3 RESTRUCTURING OF THE ELECTRICITY SECTOR, REGULATION AND TARIFF SYSTEMS IN THE REPUBLIC OF CROATIA

In the introductory part of the Round Table Discussion, the context of the legislative framework for energy and the process of the restructuring of the electricity sector, i.e. opening the electricity markets and the development and establishment of a new regulatory framework in the Republic of Croatia, were presented in detail [1], [2] and [3]. In this context and environment, methodologies for tariff systems were adopted and published, and it is necessary to determine the corresponding tariffs for the transmission and distribution of electricity and production and supply of electricity with exceptions for eligible customers.

Based upon the prevailing legislation, the Croatian Energy Regulatory Agency (henceforth: the Agency) has the obligation and responsibility, after obtaining the opinions of the energy to entities to whose activities the tariff system is applied, and the Ministry of the Economy, Labor and Entrepreneurship (henceforth: the Ministry), to adopt methodologies for the tariff systems in the sector of electricity, i.e. the tariff systems without the amounts of the tariff items, and this for 1) the generation of electricity, with the exception of eligible customers, 2) the supply of electricity, with the exception of eligible customers, 3) the transmission of electricity, 4) the distribution of electricity, 5) the determination of connection fee to the transmission and distribution networks, and increasing the installed capacity, and vi) providing the services of balancing electricity within the electricity system.

The previously cited methodologies must facilitate the investment necessary for the development of the network and other requirements, pursuant to the existing legislation.

Based upon the prevailing legislation, the energy entities to whose activities the tariff system is ap-

integralnog tarifnog sustava koji je bio na snazi više godina, razloga za njegovu promjenu, te općih značajki pristupa i kontekst regulatornih mehanizama tarifnih sustava u Republici Hrvatskoj koji su doneseni i stupili na snagu u prosincu 2006. godine [4], [5], [6] i [7]. Naravno, kroz sve te sadržaje odražava se i specifična pozicija i uloga hrvatskog energetskog regulatornog tijela – Agencije. Međutim, ogleda se i težina problema konteksta, odnosno opsega i sadržaja regulacije energetskih djelatnosti u sektoru električne energije.

Naime, nije naodmet ponoviti i činjenicu da se potreba za organizacijom Okruglog stola pojavila u momentu kada su u Republici Hrvatskoj donesena i stupila na snagu četiri nova tarifna sustava, bez visine tarifnih stavki, tj. metodologije za izračun zasebnih tarifnih stavki za djelatnosti proizvodnje, prijenosa, distribucije i opskrbe električnom energijom. Iste su do sada bile komponente jedinstvene tarife za integrirani sustav djelatnosti proizvodnje, prijenosa, distribucije i opskrbe električnom energijom, odnosno svih usluga povezanih s opskrbom električnom energijom krajnjih kupaca. Sukladno jasnoj zakonskoj obvezi razdvajanja navedenih djelatnosti, izraženih i kroz pristup spomenutim metodologijama tarifnih sustava, u tijeku su poslovi vezani uz izračun i donošenje tarifnih stavki za navedene temeljne energetske djelatnosti. Primjenom spomenutih metodologija, odnosno donošenjem i stupanjem na snagu novih tarifnih stavki elektroenergetski sektor i elektroenergetsko gospodarstvo Republike Hrvatske ući će u prvo regulatorno razdoblje.

Stoga je i za regulatorno tijelo, za predstavnike reguliranih djelatnosti, jednako tako i za stručnu javnost od velike važnosti i pomoći bilo raspraviti neka pitanja i dileme iz predmetne problematike, i to upravo na skupu s predstavnicima raznih zainteresiranih strana. Poglavito je bilo važno čuti iskustva i stavove relevantnih eksperata iz europskih regulatornih tijela i zemalja s višegodišnjim iskustvom u ekonomskoj regulaciji, bilo da se radi o dugogodišnjim članicama EU, ili zemljama koje su tek nedavno postale članice EU. U uvodnom dijelu predstavnici Agencije i reguliranih subjekata u Republici Hrvatskoj detaljno su predstavili ulogu Agencije kao regulatornog tijela, odabrane i primijenjene regulacijske pristupe i mehanizme, odnosno sadržaje i elemente metodologije tarifnih sustava koji su u Republici Hrvatskoj doneseni u prosincu 2006. godine za energetske djelatnosti prijenosa i distribucije električne energije te proizvodnje i opskrbe električnom energijom s iznimkom za povlaštene kupce [8], [9] i [10]. Okrugli stol pružio je izvrsnu prigodu za usporedbu i diskusiju hrvatskog zakonodavnog i regulatornog okružja, odnosno regulacijskog pristupa i meha-

plied submit a proposal for the amounts of the tariff items to the Ministry, which after obtaining the opinion of the Agency proposes the amounts of the tariff items to the Government of the Republic of Croatia. The Government of the Republic of Croatia determines the amounts of the tariff items. The Agency supervises the application of the tariff items and all other compensation.

At the Round Table Discussion, the context for the determination and content of the methodology of the tariff systems for the generation of electricity was presented in detail, with an exception for favored customers, as well as the supply of electricity, with an exception for favored customers, the transmission of electricity and the distribution of electricity. A presentation follows of the valid integrated tariff system that was in force for many years, the reasons for changing it, and the general characteristics of the approach and context of the regulatory mechanisms of the tariff system in the Republic of Croatia that were adopted in December 2006 and have gone into effect [4], [5], [6] and [7]. Naturally, the specific position and role of the Croatian Energy Regulatory Agency is reflected in all of this. However, the difficulty with the context of the problem, i.e. the range and content of the regulations of the energy activities in the electricity sector, are also reflected.

It is necessary to reiterate the fact that the need for the organization of the Round Table Discussion came at the moment when the Republic of Croatia had adopted and placed into force four new tariff systems, without specifying the amounts of the tariff items, i.e. the methodology for the calculation of the separate tariff items for the activities of the generation, transmission, distribution and supply of electricity. Until now, they were components of a single tariff for the integrated system of the activities of the generation, transmission, distribution and supply of electricity, i.e. all the services connected with the supply of electricity to final customers. Pursuant to the clear legal obligation for the separation of these activities, also expressed through the approach of the previously mentioned methodologies of the tariff system, work is in progress in connection with the calculation and adoption of the tariff items for these basic energy activities. Through the application of the previously mentioned methodologies, i.e. the adoption and going into force of the new tariff items of the electricity sector and the economy of the Republic of Croatia, a trial regulatory period will be entered.

Therefore, for the regulatory agency, the representatives of the regulated entities, and the professional public, it would be of great importance and benefit to discuss several questions and dilemmas regard-

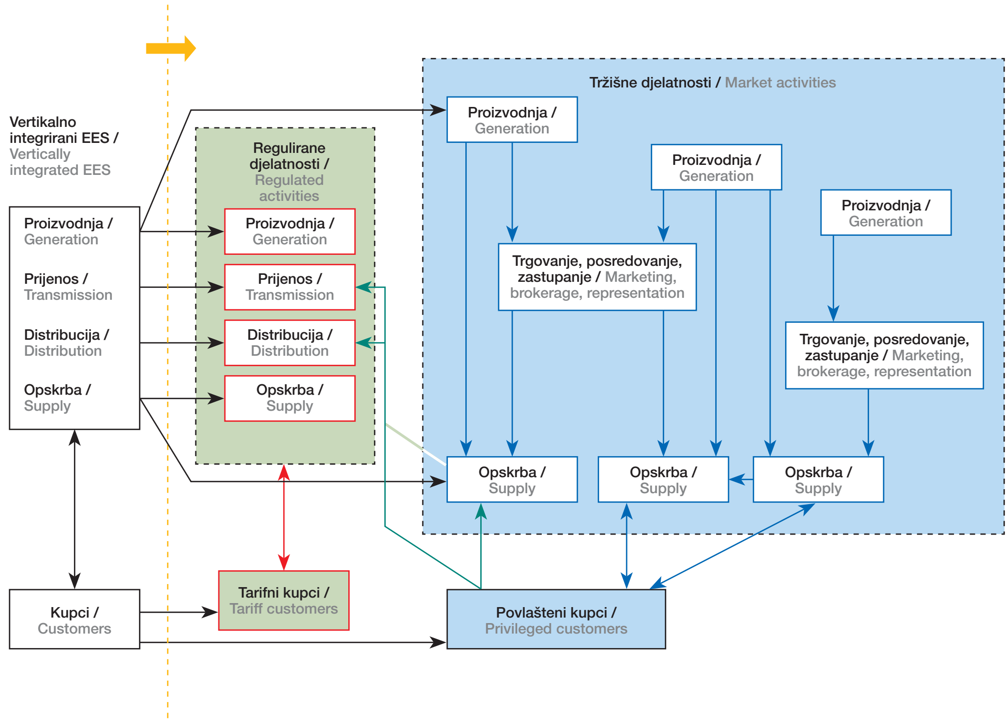
nizma, uključujući i sadržaje i elemente metodologije tarifnih sustava, s odgovarajućim okružjima, ulogama regulatornih tijela, odnosno pristupima, sadržajima i elementima regulacije i tarifnih sustava u Francuskoj, Austriji, Sloveniji i Mađarskoj i Hrvatske [11], [12], [13] i [14].

Na slici 1 prikazan je tijek procesa restrukturiranja elektroenergetskog sektora i tržišta električne energije, iz njegove vertikalno integrirane strukture u strukturu koja u svezi s tržišnim djelatnostima proizvodnje električne energije i opskrbe električnom energijom primarno podrazumijeva konkurentno okružje i tržišnu utakmicu, a glede monopolnih mrežnih infrastrukturnih sustava regulirano okružje po principu reguliranog pristupa treće strane, dakle po tarifama i ostalim uvjetima pristupa koji su unaprijed utvrđeni, razvidni i nepristrani. Specifična struktura regulacije i tarifnih sustava uvjetovana je zakonom utvrđenom obvezom javne usluge opskrbe električnom energijom tarifnih kupaca. Očito je da će tu specifičnu strukturu u budućnosti značajno uvjetovati dinamika otvaranja tržišta električne energije, tj. brzina kojom će se segment opskrbe i obveza prema tarifnim kupcima smanjivati, a segment povlaštenih kupaca rasti.

ing these problems at a meeting with the representatives of various interested parties. It would be especially important to hear about the experiences and positions of the relevant experts from the European regulatory bodies and countries with many years of experience in economic regulation, whether these countries that have been members of the EU for many years or have only recently become members of the EU. In the introductory section, representatives of the Agency and the regulated entities in the Republic of Croatia presented the role of the Agency in detail as a regulatory body, the chosen and applied regulatory approaches and mechanisms, i.e. the contents and elements of the methodologies of the tariff systems that were adopted in the Republic of Croatia in December 2006 for the energy activities of the generation of electricity, with an exception for favored customers, the supply of electricity, with the exception of favored customers, the transmission of electricity and the distribution of electricity [8], [9] and [10]. The Round Table Discussion provided an excellent opportunity for the comparison and discussion of Croatian legislation and the regulatory environment, i.e. the regulatory approach and mechanisms, including the contents and elements of the methodology of the tariff systems, with the corresponding environments, roles of the regulatory bodies, i.e. the approaches, contents and elements of the regulations and tariff systems in France, Austria, Slovenia, Hungary and Croatia [11], [12], [13] and [14].

In Figure 1, the process of the reconstruction of the electricity sector and the electricity market is presented, from its vertically integrated structure in a structure that in connection with the market activities of the generation of electricity and the supply of electricity is primarily understood to mean the competitive environment and market competition, and regarding the monopolistic network infrastructure systems, the regulated environment according to the principle of the third party acces according to tariffs and other conditions of access that have been determined in advance, and are transparent and nondiscriminatory. The specific structure of the regulatory and tariff systems was conditioned by the legally established public service obligation of the supply of electricity to tariff customers. It is evident that this specific structure will significantly affect the dynamics of the opening of the electricity market in the future, i.e. the speed at which the supply segment and the obligation toward tariff customers will be reduced and the segment of privileged customers will grow.

Slika 1
Restrukturiranje elektroenergetskog sektora i tarifni sustavi u Hrvatskoj
Figure 1
Restructuring of the electrical energy sector and the tariff systems in Croatia

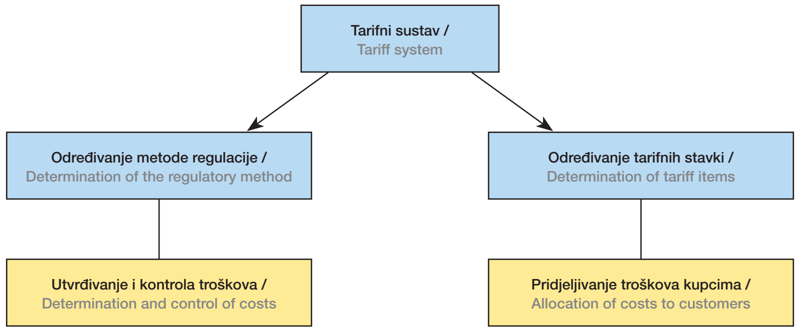



S druge strane izložena struktura ukazuje na to da je realno očekivati brze promjene konteksta, ali i sadržaja regulacije. Nije beznačajno ukazati i na dvojnost, bolje rečeno složenost regulatornog sadržaja koji s jedne strane proizlazi iz potrebe da se definiraju sadržaji i razrađuju specifični elementi ekonomske regulacije za segment tzv. prirodnih monopolnih djelatnosti prijenosa i distribucije električne energije, koje su u pravilu svugdje ujedno i regulirane djelatnosti, a s druge strane iz potrebe da se, premda ipak privremeno i do potpunog otvaranja tržišta električne energije, razviju i uvedu regulacijski mehanizmi za tržišne djelatnosti proizvodnje i opskrbe električnom energijom. Tržišne djelatnosti općenito i općeprihvaćeno trebaju biti izložene konkurenciji. To samo svjedoči o težini zadatka i izazova s kojima se suočava regulatorno tijelo, ali i regulirani subjekti, kada je proizvodnju i opskrbu potrebno prevesti iz stanja monopola u stanje konkurencije.

Na slici 2 prikazana je osnovna struktura, odnosno sadržaji novih tarifnih sustava kako ih definira novi zakonodavni okvir u Republici Hrvatskoj.

On the other hand, the presented structure indicates that it is realistic to anticipate rapid changes in the context as well as the contents of regulation. It is necessary to mention the duality, better to say the complexity, of the regulatory content that from the one side issues from the need to define the contents and work out the specific elements of the economic regulation of this segment, the so-called naturally monopolistic activities of the transmission and distribution of electricity, which as a rule are also regulated activities everywhere; and from the other side the need for, albeit temporarily and until the complete opening of the electricity market, the development and introduction of the regulatory mechanisms for the market activities of the generation and supply of electricity. Market activities should generally be exposed to competition. This only testifies to the difficulty of the task and the challenges confronting the regulatory agency, but also the regulated entities, when generation and supply must be changed from a state of monopoly to a state of competition.

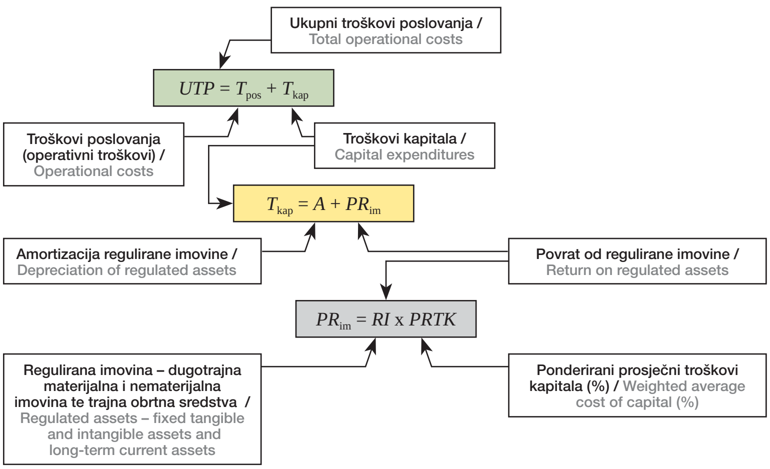
In Figure 2, the basic structure, i.e. content, of the new tariff systems is presented as defined by the new legislative framework in the Republic of Croatia.




**Slika 2**
Osnovna struktura i sadržaj novih tarifnih sustava
**Figure 2**
The basic structure and content of the new tariff systems

Ključni moment ili sadržaj regulacijskog procesa u kojem se definira pristup novom tarifnom sustavu je izbor osnovnog pristupa metodi regulacije (slika 3).

The crucial moment or content of the regulatory process in which the access to the new tariff system is defined is the selection of the basic approach to the method of regulation (Figure 3).




**Slika 3**
Izbor, sadržaj i mehanizam regulacije u novim tarifnim sustavima
**Figure 3**
The selection, content and mechanism of regulation in the new tariff systems

Ocjenjujući realnim i razumnim da se na početku prvog regulatornog razdoblja, dakle kada se po prvi put izlazi iz dugogodišnje integrirane tarifne strukture i jedinstvenih tarifnih stavki za sve energetske djelatnosti u sektoru električne energije i prelazi na odvojene pristupe i zasebne tarifne stavke za svaku od tih djelatnosti, odabere što jednostavniji, lakše primjenjiv i provedivi pristup i mehanizam, odabrana je opće poznata metoda priznatih troškova poslovanja, pri čemu se regulacija zapravo temelji i veže za kriterij stope povrata uloženog kapitala (eng. *Cost Plus* ili *Rate-of Return Regulation*). Dakle, slijedilo se odgovarajuće iskustvo i praksu više europskih zemalja i njihovih regulatornih tijela, koja su u početku procesa uvodila jednostavne regulacijske mehanizme, a

At the beginning of the first regulatory period, i.e. when for the first time the integrated tariff structure and single tariff items for all the energy activities in the power system will be replaced in transition to separate approaches and separate tariff items for each of these activities, it is realistic and reasonable to choose the simplest possible, easily applicable and feasible approach and mechanism. The generally known method of recognized costs of operations has been chosen, so that the regulation is actually based upon and connected with the criterion of the rate of return on investments. Furthermore, the corresponding experience and practice have been followed of several European countries and their regulatory agencies, which introduced simple regulatory mechanisms at the beginning of the process and then,

zatim s vremenom, kako su svi sudionici procesa stjecali odgovarajuća znanja i iskustva, uvodili sve složenije mehanizme, da bi danas primjenjivali složene mehanizme poticajne regulacije, ali i vrlo složene i zahtjevne procedure nadzora i kontrole svakog segmenta tih mehanizama. Tako npr. često su u regulacijske mehanizme uključeni neki od makroekonomskih gospodarskih parametara i pokazatelja, koji traže vrijeme za složenu i dugotrajnu analizu i elaboraciju. U pravilu se pokazuje da nije niti jednostavno niti opravdano bez ograde koristiti istovrsne pokazatelje primijenjene u drugim zemljama, pa čak niti prenositi i koristiti istovrsne pokazatelje primijenjene u drugim gospodarskim sektorima iste zemlje. Pogotovo je oprez nužan kada su u pitanju razina i struktura, odnosno način utvrđivanja odgovarajućih pokazatelja tržišnih rizika u svezi s ulaganjima, vlastitim kapitalom, dugovanjima i slično.

Zakon utvrđuje da se tarifni sustavi temelje na opravdanim troškovima poslovanja, održavanja, zamjene, izgradnje ili rekonstrukcije objekata i zaštite okoliša, uključujući razuman rok povrata sredstava od investicija u energetske objekte, uređaja i mreža, odnosno sustava, te moraju biti nepristrani i razvidni. Ujedno, tarifni sustavi trebaju poticati mehanizme za poboljšanje energetske učinkovitosti i upravljanje potrošnjom, uključujući i povećano korištenje obnovljivih izvora energije. Dakle, kod odabira temeljnog pristupa regulacije bilo je nužno voditi računa da prihod ostvaren primjenom novih tarifnih stavki treba pokriti sve priznate ukupne troškove poslovanja, dakle priznate operativne troškove i troškove kapitala, od kojih troškove kapitala čine amortizacija regulirane imovine i povrat od regulirane imovine.

U hrvatskoj literaturi često se miješaju dva različita pojma:

- kapitalni troškovi *(CAPEX, Capital Expenditures),*
- trošak kapitala *(CC, Cost of Capital, odnosno WACC, Weighted Average CC).*

Reguliranom energetskom subjektu u općem slučaju treba omogućiti nadoknadu svih (priznatih) operativnih troškova, amortizacije, te troškova koje potražuju vlasnici financijskog kapitala, a to su:

- kamate i prinosi emitiranih korporacijskih obveznica,
- oportunitetni trošak vlasnika dioničarskog kapitala.

with time, when all the participants in the process had acquired the appropriate knowledge and experience, introduced progressively complex mechanisms in order to apply more complex mechanisms and incentive regulation today, but also highly complex and demanding procedures for the supervision and control of each segment of these mechanisms. Thus, for example, regulatory mechanisms frequently included some of the macroeconomic parameters and indices, which require time for complex and lengthy analysis and elaboration. As a rule, it has been shown that it is neither simple nor justifiable to use the same types of indices applied in other countries without limitation, or even to transfer and use the same types of indices applied in the other economic sectors of the same country. Caution is particularly necessary when the level and structure are in question, i.e. the manner of determining the corresponding indices of market risks in connection with investments, equity capital, debts etc.

The law establishes that the tariff systems are based upon the justified costs of the operations, maintenance, replacement, construction or reconstruction of facilities and environmental protection, including a reasonable period for the return of investments in energy facilities, equipment and networks, i.e. the systems, and must be nondiscriminatory and transparent. At the same time, tariff systems must promote mechanisms for the improvement of energy efficiency and the management of consumption, including the increased use of renewable energy sources. Therefore, in the selection of the basic approach to regulation, it was necessary to take into account that the income generated through the application of the new tariff items should cover all the known overall operational costs, i.e. the recognized operational costs and capital expenditures, which consist of the depreciation of the regulated property and the return from the regulated property.

In the Croatian literature, two different concepts are often confused:

- capital expenditures (*CAPEX*),
- cost of capital (*CC*, Cost of Capital, or *WACC*, Weighted Average *CC*).

Through the regulation of an energy entity in the general case, it is necessary to facilitate compensation for all (recognized) operative costs, depreciation and expenditures claimed by the owners of capital, as follows:

- interest and the income from corporate bonds issued,
- opportunity costs for stockholders.

Stopa povrata koja omogućuje naknadu troškova iz navedene dvije kategorije zove se ponderirani prosječni trošak kapitala *(WACC)*.

Po odabranom pristupu i metodi regulacije, određivanje visine tarifnih stavki za buduću regulacijsku godinu zasniva se na sljedećim troškovima:

a) priznatim ostvarenim troškovima poslovanja iz prethodne regulacijske godine,
b) ostvarenim i procijenjenim troškovima poslovanja za sadašnju regulacijsku godinu, te
c) prihvaćenim planskim vrijednostima troškova za razmatranu buduću regulacijsku godinu.

U reguliranu imovinu, temeljem koje se primjenom odgovarajuće priznate stope ponderiranog prosječnog troška kapitala računa povrat ili prinos od regulirane imovine, čine dugotrajna materijalna i nematerijalna imovina te trajna obrtna sredstva. Izložena osnovna struktura ili pristup primjenjuje se na sve djelatnosti: proizvodnju, prijenos, distribuciju i opskrbu električnom energijom.

Specifična temeljna struktura i osnovne stavke troškova poslovanja u svezi s proizvodnjom električne energije prikazana je na slici 4, u svezi s prijenosom električne energije na slici 5, s odgovarajućom posebnom razradom potrebnih podataka koja je prikazana na slici 6, u svezi s distribucijom električne energije na slici 7, te u svezi s opskrbom električnom energijom na slici 8.

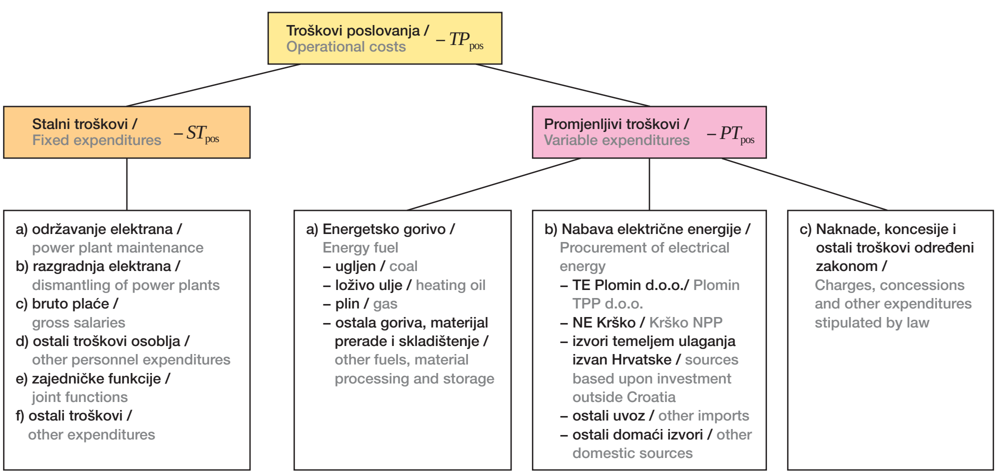
The rate of return that makes compensation for costs from the two cited categories possible is known as the weighted average cost of capital (WACC).

According to the selected approach and method of regulation, the determination of the level of the tariff items for the subsequent regulated year is based upon the following expenditures:

a) the recognized realized costs of operations during the previous regulated year,
b) the realized and estimated costs of operations for the current regulated year, and
c) the accepted planned values of expenditures for the analyzed subsequent regulated year.

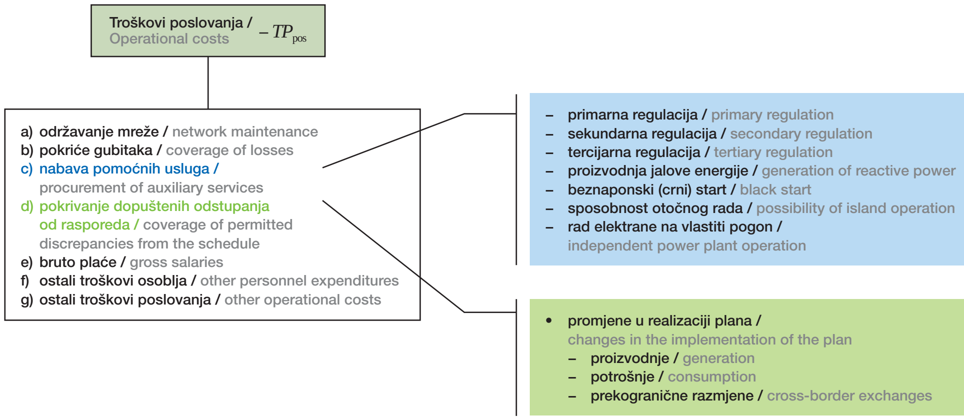
For regulated property, according to which the corresponding recognized rate of the weighted average cost of capital is applied, the return or revenue is calculated and consists of fixed tangible assets, intangible assets and permanent current assets. The basic structure or approach presented is applied to all activities: the generation, transmission, distribution and supply of electricity.

The specific fundamental structure and basic items of operational costs in connection with the generation of electricity are presented in Figure 4, in connection with the transmission of electricity in Figure 5, with the corresponding separate processing of the necessary data presented in Figure 6, the distribution of electricity in Figure 7 and in connection with the supply of electricity in Figure 8.

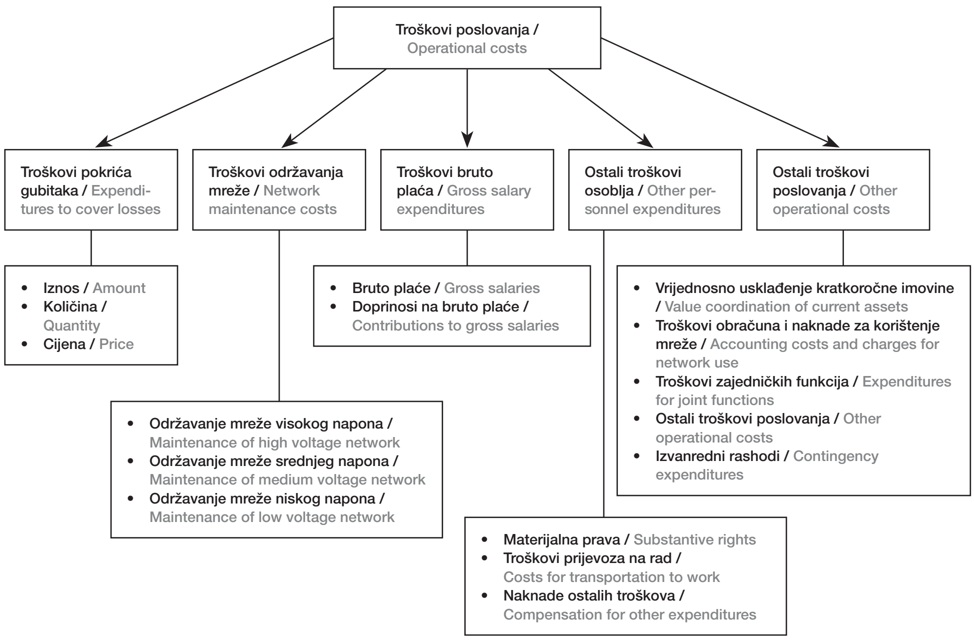



**Slika 4**
Tarifni sustav za proizvodnju električne energije (struktura troškova)
**Figure 4**
The tariff system for the production of electrical energy (the structure of expenditures)

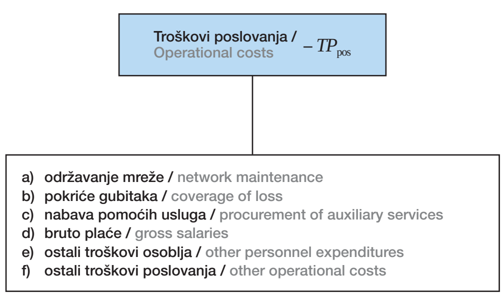
**Slika 5**
Tarifni sustav za prijenos električne energije (struktura troškova)
**Figure 5**
The tariff system for the transmission of electrical energy (the structure of expenditures)

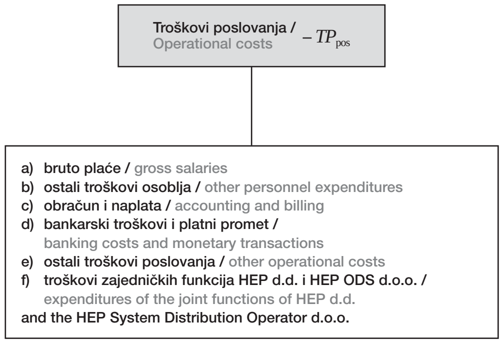



**Slika 6**
Tarifni sustav za prijenos električne energije (struktura potrebnih podataka)
**Figure 6**
The tariff system for the transmission of electrical energy (the structure of the required data)




**Slika 7**
Tarifni sustav za distribuciju električne energije (struktura troškova)
**Figure 7**
The tariff system for the distribution of electrical energy (the structure of expenditures)






**Slika 8**
Tarifni sustav za opskrbu električnom energijom (struktura troškova)
**Figure 8**
The tariff system for the supply of electrical energy (the structure of expenditures)

Glede prijenosa električne energije, bolje rečeno HEP Operatora prijenosnog sustava problematiku pristupa regulaciji, odnosno tarifnom sustavu još složenijima čine i sljedeća pitanja, odnosno problemi novog okružja, kao što su:

– poslovanje HEP Operatora prijenosnog sustava na otvorenom tržištu,
– način utvrđivanja i tretmana troškova nastalih zbog prekograničnih tranzita električne energije,
– potreba da se u kratkom vremenu razradi trogodišnji plan razvoja i izgradnje u novom okružju i po novoj metodologiji (problem okvira i temeljnih odrednica za donošenje plana u znatno restrukturiranom okružju u koji se uvode tržišni odnosi, stvaraju pretpostavke za regulirani pristup trećih strana mrežama i uslugama sustava, ulaze novi sudionici, stvara novo poticajno okružje za veće korištenje obnovljivih izvora energije, jednom riječju mijenjaju dosadašnji tradicionalni odnosi i struktura odgovornosti),
– kako napraviti djelotvornu analizu osjetljivosti cijene za korištenje prijenosne mreže, koja sada postaje zasebna stavka,
– kako osigurati pomoćne usluge sustava i na razvidan i pravedan način pridijeliti ih korisnicima i naplatiti,
– kako obuhvatiti i na djelotvoran način analizirati utjecaj vjetroelektrana i drugih postrojenja koja koriste obnovljive izvore energije na pogonske parametre mreže, ali i na troškove korištenja prijenosne mreže,
– kako ustanoviti djelotvoran mehanizam proračuna troškova upravljanja zagušenjima mreže,
– da li ustanoviti odvojeno računovodstvo i kako, itd.

Glede distribucije električne energije, bolje rečeno HEP Operatora distribucijskog sustava problematiku pristupa regulaciji i tarifnom sustavu dodatno prati problematika nestandardnih usluga: njihova

Regarding the transmission of electricity, better to say the HEP Transmission System Operator, the problem of the approach to regulation, i.e. the tariff system, is further complicated by questions and problems of the new environment, including the following:

– the operations of the HEP Transmission System Operator on the open market,
– the manner of the determination and treatment of costs occurring due to the cross-border transit of electricity,
– the necessity of preparing a three-year development and construction plan in a short time within the new environment and according to new methodology (the problem of the framework and fundamental determinants for the adoption of the plan in the significantly restructured environment into which market relations are being introduced, creating the prerequisites for the regulated access of third parties to the system networks and services, the entry of new participants, the creation of a new incentive environment for the increased use of renewable energy sources, i.e. the traditional relationships and structure of responsibilities are changing),
– how to prepare an effective analysis of price sensitivity for the use of the transmission network, which presently represents a separate item,
– how to secure auxiliary system services, allocate them to users and charge for them in a transparent and fair manner,
– how to include and efficiently analyze the impact of wind power plants and other facilities that use renewable energy sources on the network operating parameters, but also on the costs of using the transmission network,
– how to establish an efficient mechanism for calculating the costs of the management of network congestion,
– whether and how to establish separate accounting etc.

Regarding the distribution of electricity, better to say the HEP Distribution System Operator, the problem of

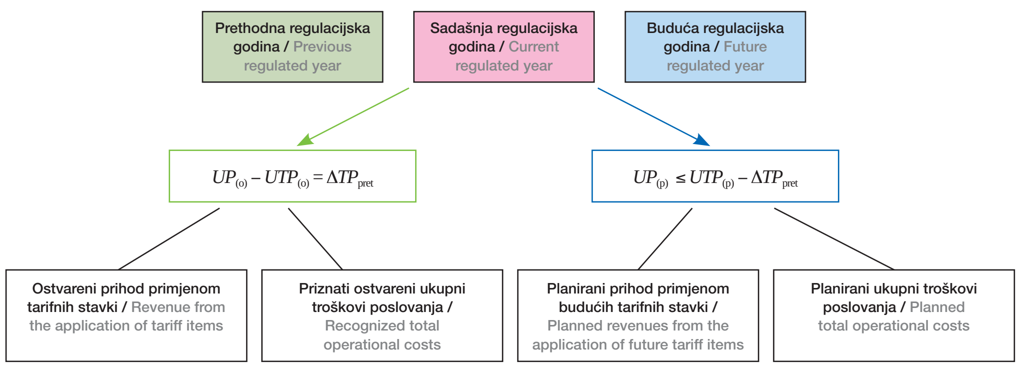
knjigovodstvenog praćenja po izdvojenim kontima i njihova odvajanja od standardnih usluga kod praćenja troškova. Problem je i rasporeda troškova prema njihovoj vrsti te utvrđivanja elemenata za proračun povrata na reguliranu imovinu.

Tijek procesa utvrđivanja i predlaganja visine tarifnih stavki prikazan je na slici 9.

the approach to the regulation and tariff system is additionally accompanied by the problem of nonstandard services; bookkeeping records according to separate accounts and their separation from "standard" services in monitoring expenditures. There is also the problem of the distribution of expenditures according to their type and the determination of the elements for the calculation of returns on regulated property.

The process for the determination and proposal of the amounts of the tariff items is presented in Figure 9.

**Slika 9**
Novi tarifni sustavi (proces predlaganja visine tarifnih stavki)
**Figure 9**
New tariff systems (the process of proposing the amounts of tariff items)




Prethodna godina je godina koja prethodi godini za koju se donose tarifne stavke za odgovarajuću energetsku djelatnost, a za koju su revidirani i objavljeni financijski podaci, poznat ukupni prihod primjenom vrijedećih tarifnih stavki i poznati ostvareni ukupni troškovi poslovanja. Sadašnja regulacijska godina je tekuća godina u kojoj se podnosi prijedlog promjene visine tarifnih stavki za buduću regulacijsku godinu. Prijedlog promjene visine tarifnih stavki za odgovarajuću energetsku djelatnost podnosi energetski subjekt na koji se te tarifne stavke odnose. Energetski subjekt dužan je uz prijedlog za promjenu visine tarifnih stavki dostaviti sve podatke potrebne za utvrđivanje troškova poslovanja, posebno financijsko izvješće za prethodnu regulacijsku godinu potvrđeno od ovlaštenog neovisnog revizora te plan poslovanja i plan razvoja i izgradnje (za sadašnju i buduću regulacijsku godinu). Navedeni dokumenti moraju biti potpisani od ovlaštene osobe energetskog subjekta i ovjereni pečatom tvrtke. Na zahtjev Ministarstva ili Agencije energetski subjekt dužan je dostaviti i druge podatke potrebne za utvrđivanje promjene visine tarifnih stavki te omogućiti uvid u pripadnu dokumentaciju. Prijedlog promjene visine tarifnih stavki za buduću regulacijsku godinu energetski subjekt dužan je dostaviti u sadašnjoj regulacijskoj godini, a nakon što za nju budu po-

The previous year is the year that precedes the year for which tariff items are adopted for the corresponding energy activity, and for which the financial data are revised and published: the known total revenue through the application of the valid tariff items and the known realized total operational costs. The current regulatory year is the current year in which a proposal is submitted for changing the amount of tariff items for the subsequent regulatory year. A proposal for a change in the amount of tariff items for the corresponding energy activity is submitted by an energy entity to which the tariff items apply. Together with the proposal for the change in the amount of tariff items, the energy entity is required to submit all data necessary for the determination of the operational costs, especially the financial report for the previous regulatory year audited by an authorized independent auditor, a plan of operations, and a plan of development and construction (for the current and future regulatory years). These documents must be signed by the authorized person of the energy entity and stamped with the company seal. At the request of the Ministry or Agency, the energy entity is required to submit other data necessary for determining the changes in the amounts of tariff items and facilitate the inspection of the corresponding documentation. A proposal for changes in the amount of tariff items for the subsequent regulatory year must be submit-

znati polugodišnji ukupni troškovi poslovanja. I konačno, energetski subjekt dužan je predložiti promjenu visine tarifnih stavki uz uvjet da očekivani prihod u budućoj regulacijskoj godini, izračunat prema odgovarajućem tarifnog sustava, ne prelazi prihvaćene planirane ukupne troškove poslovanja, korigirane za eventualna opravdana ili odobrena odstupanja.

Pored prethodnog bitno je istaći da su utvrđene i sljedeće obveze energetskih subjekata:

– rok za usklađivanje poslovanja s odredbama tarifnog sustava je šest mjeseci,
– obveza dostavljanja podataka, posebno plana poslovanja te plan razvoja i izgradnje, odnosno trogodišnjeg plana razvoja i izgradnje, kojeg subjekt donosi uz suglasnost Agencije, i to:
  · do 31. 5. sadašnje regulacijske godine – financijska izvješća za prethodnu regulacijsku godinu potvrđena od ovlaštenog neovisnog revizora,
  · do 30.11. sadašnje regulacijske godine - planovi poslovanja.

## 4 ZAKLJUČCI OKRUGLOG STOLA O ULOZI REGULATORNOG TIJELA U DONOŠENJU TARIFNIH SUSTAVA

Nakon svih prezentacija i rasprava u kojima su sudjelovali predstavnici regulatornih tijela iz Francuske, Austrije, Slovenije, Mađarske i Hrvatske, te predstavnici Hrvatske elektroprivrede d.d., odnosno predstavnici energetskih subjekta u Republici Hrvatskoj za koje se donose i primjenjuju odgovarajući tarifni sustavi, utvrđeni su zaključci Okruglog stola. Ti zaključci su bili kako slijedi:

1) Okrugli stol uspješno je organiziran i proveden i u potpunosti je opravdao razloge organiziranja, ponudivši niz odgovora na važna pitanja i dileme glede pristupa, sadržaja i forme regulacije, provedbenih procedura i metodologija regulacije, metodologija tarifnih sustava i strukture samih tarifnih stavki. Naravno, sudionici nisu propustili naglasiti i pojasniti niz provedbenih ili proceduralnih, dakle pojavnih i praktičnih problema s kojima se susreću regulatorna tijela i regulirani energetski subjekti, naročito oni koji su nositelji monopolnih djelatnosti i obveza javnih usluga.

2) Predavači su sudionike Okruglog stola uveli u predmetnu problematiku i ukazali im na opću prisutnost sličnih pitanja i dilema u svim zemlja-

ted by an energy entity during the current regulatory year, and after it knows the total operational costs for the first half of the year. Finally, the energy entity is required to propose a change in the amount of tariff items under the condition that the anticipated revenue in the subsequent regulatory year, calculated according to the corresponding tariff system, does not exceed the accepted planned total operational costs, corrected for eventual justified or authorized discrepancies.

In addition to the above, it is essential to emphasize that the following obligations of energy entities have also been determined:

– the deadline for the coordination of operations with the provisions of the tariff system is six months,
– the obligation for the submission of data, especially a plan of operations and a plan for development and construction, i.e. a three-year plan for development and construction, that the subject adopts with the approval of the Agency, as follows:
  · by May 31 of the current regulatory year – financial reports for the previous regulatory year that have been audited by an authorized independent auditor, and
  · by November 30 of the current regulatory year – operational plans.

## 4 CONCLUSIONS OF THE ROUND TABLE DISCUSSION ON THE ROLE OF THE REGULATORY BODY IN THE ADOPTION OF NEW TARIFF SYSTEMS

Following all the presentations and discussions in which the participants were the representatives of the regulatory agencies of France, Austria, Slovenia, Hungary and Croatia; representatives of Hrvatska elektroprivreda d.d., and representatives of the energy entities in the Republic of Croatia for whom the corresponding tariff systems are being adopted and applied, conclusions were reached by the Round Table, as follows:

1) The Round Table was organized and conducted successfully. It fully justified the reasons for which it was held, providing a range of answers to important issues and dilemmas related to the approach, regulatory contents and form, implemented procedures, regulatory methodology, tariff system methodology and the structure of the tariff items themselves. The participants emphasized and explained a range of implementational or procedural issues, i.e. actual and practical issues that the regulatory agencies and regulated entities encounter, especially those with monopolies and public service obligations.

ma, kod svih regulatornih tijela i svih reguliranih energetskih subjekata. Naravno, u zemljama u kojima su odgovarajuća energetska regulatorna tijela osnovana tek nedavno, u kojima određeni procesi restrukturiranja i novog organiziranja elektroenergetskog sektora nisu u potpunosti dovršeni, u kojima je proces otvaranja tržišta električne energije i uvođenje konkurencije tek u početnoj fazi, i konačno u kojima odgovarajuće makroekonomske pokazatelje i utjecajne regulatorne parametre nije nimalo lako i jednostavno utvrditi, puno je veći broj i pitanja i dilema. Oblik prenošenja znanja i stečenih iskustava, kakav je uostalom ponudio i ovaj Okrugli stol, ukazuje na nužnost i potrebu organizacije istih ili sličnih formi i sadržaja rada na nacionalnoj, regionalnoj, pa i široj međunarodnoj razini, bilo da se radi o okruglim stolovima, radionicama, seminarima ili konferencijama.

3) Okrugli stol naglasio je da je bez obzira na različita iskustva i dinamiku procesa, i bez obzira na opći zakonodavni i gospodarski sustav iz kojeg dolazi, odgovarajući vrijedeći zakonodavni okvir u svakoj državi mora osigurati uvjete za nezavisan, nepristran i razvidan rad energetskog regulatornog tijela. Unutar toga zakonodavnog okvira nadležno državno tijelo i regulatorno tijelo imaju obvezu i dužnost izgraditi i primijeniti utemeljene, realne, razvidne i lako provedive mehanizme i metodologije regulacije, odnosno metodologije tarifnih sustava. O raznim oblicima ili sadržajima, političkim i gospodarskim utjecajima nužno je voditi računa utoliko što su oni stalno prisutni, što su izrazi raznih nacionalnih strategija ili interesa, dakle predstavljanju važan element realnog okružja u kojem se odvija život i rad regulatornog tijela i reguliranih energetskih subjekata, i u kojem se uspostavlja tržište električne energije.

4) Okrugli stol naglasio je suštinsku uvjetovanost problema regulacije reguliranih energetskih djelatnosti, naročito monopolnih mrežnih sustava i javnih usluga dinamikom otvaranja i načinom uređenja tržišta električne energije. Pravo pristupa mrežama i pomoćnim uslugama sustava prvo je u nizu problema s kojima se treba susresti. Nema dvojbe da se pravo pristupa treba i mora urediti unaprijed kroz odgovarajuća mrežna pravila i tehničke uvjete, ali da bi se moglo ostvarivati u nepristranom, razvidno i nediskriminirajućem okružju, nužno je unaprijed utvrditi i objaviti i tehničke i ekonomske uvjete priključka i naknade za korištenja prijenosne i distribucijske mreže, te uvjete i naknade za korištenje pomoćnih usluga sustava, naravno u slučaju da su iste obuhvaćene odgovarajućim regulatornim okvirom.

5) Okrugli stol jasno je pokazao prednost u iskustvu i rješenjima regulatornih tijela, odnosno

2) The lecturers introduced the issues to the Round Table Discussion participants and called attention to the general presence of similar questions and dilemmas in all the countries, regulatory agencies and regulated electrical power entities. Naturally, there are many more questions and dilemmas in countries where the energy regulatory agencies have only been recently established and certain processes of the restructuring and reorganizing of the electricity sector have not been fully completed, where the processes of opening the electricity market and the introducing of competition are in the initial phases and, finally, where the corresponding macro-economic indices and influential regulatory parameters are not easy to determine. The form of the transfer of knowledge and acquired experience, as provided at this Round Table Discussion, indicates the necessity for organizing similar events at the national, regional and even international levels, in the form of round table discussions, workshops, seminars or conferences.

3) The Round Table Discussion emphasized that, regardless of differences in experiences and process dynamics, and regardless of the general legal and economic system, the appropriate valid and transparent legal framework in each country must provide conditions for the independent, nondiscriminatory and transparent operation of the energy regulatory agency. Within this legal framework, the authorized government agency and regulatory agency have the obligation and duty to build and implement well-founded, realistic, transparent and feasible regulatory mechanisms and tariff system methodologies. It is necessary to take the various forms and contents of the prevailing political and economic influences into account, which are expressions of various national strategies or interests, i.e. they represent an important element of the actual environment in which the regulatory agency and the regulated electrical power entities function, and in which the electricity market is established.

4) The Round Table Discussion highlighted an essential correlation among the issues of the regulation of regulated activities, especially monopolistic network systems and public services, in the dynamics of the opening of electricity markets and the manner of their organization. The right to access the networks and auxiliary services of the system is the first in a series of issues that must be addressed. There is no doubt that the right to access must be defined in advance through appropriate network rules and technical conditions. In order for this right to be exercised in an nondiscriminatory, transparent and non-discriminatory environment, it is necessary to predetermine and publish the technical and economic prerequisites for electricity connections, charges for using the transmission and distribution networks, and the conditions and charges for the use of the

država i njihovih odgovarajućih energetskih sektora i gospodarskih subjekata, koji su u spomenute procese i problematiku ušli ranije. S druge strane, prednost zemalja, njihovih energetskih sustava i gospodarstava, dakako i njihovih regulatornih tijela, koji su procese otvaranja tržišta električne energije i uvođenja novih oblika regulacije započeli tek nedavno, da mogu koristiti odgovarajuća iskustva zemalja u kojima su tržišta električne energije uspostavljena i razvijena ranije, i kojima je regulacija ušla u više faze i razdoblja primjene, pri tom ne ponavljajući njihove zablude i kriva rješenja.

6) U pogledu regulacije energetskih djelatnosti prednost je država i ekonomija, uključujući i energetski sektor, koji imaju dobro praćenje i izvještavanje o adekvatnim makroekonomskim gospodarskim parametrima, kao što su interesne, odnosno kamatne stope na vlastiti kapital i zaduženja, stope inflacije, premije na tržišne rizike, prinose od rizičnih i nerizičnih ulaganja, pokazatelje u svezi s prinosom dionica, premije za tržišni rizik vlastitog kapitala itd. Jednoznačni prijenos i primjena navedenih parametara iz jednog nacionalnog u drugi nacionalni energetski gospodarski sustav ili regulatorni okvir vrlo je dvojben i prati ga niz pitanja i dvojbi. Tim više što ne samo da nema jednoznačnih kriterija, nego su i vrlo različiti pristupi utvrđivanju osnovica, npr. vrijednosti imovine i regulatorne osnovice, na koje se navedeni parametri primjenjuju. U tom kontekstu i ciljani financijski pokazatelji, kao što je to npr. stopa povrata na imovinu ili pak garantirani vremenski rok povrata uloženih sredstava, u posljednje vrijeme sve češće postaju predmetom preispitivanja, nerijetko čak i važno političko pitanje na nacionalnoj razini. Naime, s navedenim pitanjima usko su povezani problemi novih investicija i ulaganja u elektroenergetske sustave, ali i pitanja profita iz energetskih djelatnosti. Svaki od navedenih ekonomskih veličina i parametara dakako ima svoj odraz u odgovarajućem utjecaju na ekonomičnost poslovanja energetskog subjekta i njegovu sposobnost da se dalje razvija.

U okviru diskusije konstatirano je da bi bilo dobro i pragmatično da prve razvojne faze ekonomske regulacije prate i relativno jednostavne regulacijske sheme tipa *cost plus* ili povrata sredstava, da bi nakon stjecanja određenih iskustava i znanja uslijedio razvoj puno složenijih shema koje uključuju kombinacije tehničkih i ekonomskih inicijativa koje kroz dugoročni period trebaju osigurati sigurno i stabilno financiranje rada i adekvatni razvoj reguliranih energetskih subjekta, naročito velikih mrežnih infrastrukturnih sustava za prijenos i distribuciju električne energije. Opći konačni cilj je dakako sigurna opskrba električnom energijom po realnoj, odnosno opravdanoj cijeni.

auxiliary system services in the event that these are covered by the corresponding regulatory framework.

5) The Round Table Discussion clearly demonstrated the superiority of the experience and solutions of the regulatory bodies, countries, energy sectors and economic entities which had addressed these processes and problems earlier. On the other hand, the countries, energy systems, economies and certainly regulatory agencies that have only begun the processes of opening the electricity markets and introducing new forms of regulations have the advantage of being able to utilize the experiences and avoid repeating the past errors and inadequate solutions of the countries in which the electricity markets have already been established and developed, and in which regulations have entered advanced phases and periods of application.

6) In the regulation of energy activities, the governments and economies, including the energy sectors, that have good tracking and reporting of macroeconomic parameters such as interest rates on equity and debt, inflation rates, market risk premiums, yields from high-risk and low-risk investments, indices in connection with stock market yields, equity-risk premiums etc. are at an advantage. The direct transfer and application of these parameters from one national power system or regulatory framework to another is not practicable because a number of issues and dilemmas are involved. This is even more the case because there are no uniform criteria. Instead, there are highly varied approaches for the determination of the bases, for example the asset-value base and regulatory base to which the given parameters are applied.

In this context, the target financial indices such as the rate of return on assets or the guaranteed period of return on investment have lately become subjected to increasing scrutiny and are frequently an important political issue at the national level. Closely related to these issues are the problems of new investments in power systems, as well as the question of profit from electricity activities. Each of these economic measurements and parameters certainly influence the cost-effectiveness of the operations of entities and their ability to continue to develop.

Within the framework of the discussion, it was concluded that it would be good and pragmatic for the first development phases of economic regulation to accompany relatively simple regulation schemes of the “cost plus” or “return on assets” type. After experience and knowledge are acquired, this should be followed by the development of more complex schemes that include a combination of technical and economic initiatives, which over the long run should assure the secure and stable financing of operations

7) Regulatorna tijela imaju važnu ulogu u procesu odobravanja i nadzora provedbe razvojnih planova reguliranih subjekata, tj. prijenosne i distribucijske mreže i sustava, odnosno nadzornu ulogu u pogledu kvalitete i sigurnosti usluga i funkcija koje obavljaju ti energetski subjekti, ali i opskrbe krajnjih kupaca i korisnika u cjelini. Pristupi i praksa u različitim zemljama razlikuju se.

Ima primjera duboke uključenosti i odgovornosti regulatornog tijela u svim fazama i elementima planiranja (odobravanje i nadzor provedbe planova), osiguranja sredstava kroz naknade i poticajne elemente tih naknada (kapitalni troškovi, povrati na kapital), te općeg procesa nadzora rada reguliranog energetskog subjekta. S druge strane, uloge nekih regulatornih tijela u početku nisu podrazumijevala obilježja duboke uključenosti. Nadomjestak dubljem regulatornom nadzoru bili su opći pristupi po kojim su npr. planirane investicije iz razvojnih planova i planova izgradnje bile odobravane do određene razine i kao takve uključene u naknade za korištenje mreže. Ima primjera i manje involviranosti regulatornog tijela u početnim fazama uvođenja regulacije ili tijekom početnih regulatornih perioda. Međutim, odmakom procesa i sve većom involviranosti regulatornog tijela u više slučajeva dovelo je do smanjenja naknada za korištenje mreža.

8) Navedeni tijek gotovo u potpunosti poklapa se s tijekom uvođenja složenih regulatornih pristupa i metodologija ekonomske regulacije, odnosno metoda poticajne regulacije energetskih djelatnosti. Iz svega prethodnog izveden je zaključak da se u početku trebaju što bolje i preciznije definirati odgovornosti regulatornog tijela i reguliranih subjekata. Nadalje, u novonastalim i tržišnim okolnostima trebaju se dobro obuhvatiti i obrazložiti svi važni parametri, utjecajne veličine i okolnosti tržišnog okružja koje se uvodi, Posebno je važno krenuti s jednostavnijim regulatornim pristupima i metodama, i to u pravilu s kraćim regulatornim periodima. Svaka od mogućih nesigurnosti ili skrivenih mana u regulatornom pristupu, krivo procijenjenog utjecajnog parametra ili ciljanog ekonomskog indeksa, nepredviđene loše posljedice procesa restrukturiranja u dinamičnom tržišnom okružju, ali na kraju i posljedice moguće krive odluke regulatornog tijela, vodi ili vrlo visokim ili nedopustivo niskim iznosima naknada za korištenje mreža. Visoki iznosi naknada za korištenje mreža znače ne samo visoke troškove za korisnike mreža, nego, pogotovo za one izvan dosadašnjih integriranih nacionalnih elektroenergetskih sustava, i značajnu prepreku za ulazak na tržište električne energije, a time i njegovom razvoju. Iskazani neopravdano visoki iznosi profita u monopolnim djelatnostima imaju i daljnje negativne političke i socijalne posljedice, čak,

and the adequate development of the regulated energy entities, especially the large network infrastructure systems for the transmission and distribution of electricity. The general goal is, of course, a secure supply of electricity at a realistic, i.e. justified, cost.

7) The regulatory agencies have an important role in the process of the authorization and supervision of the implementation of the plans for the development of the regulated entities, i.e. the transmission and distribution networks and systems, and a supervisory role over the quality and security of the services and functions performed by these energy entities, as well as supply to the end users and users in general. The approaches and practices in various countries differ.

There are regulatory agencies that are deeply involved in and responsible for all the phases and elements of planning (the authorization and supervision of plan implementation), obtaining funds through charges and the incentive elements of these charges (capital expenditures, return on equity) and the general supervisory process of the operations of a regulated entity. On the other hand, initially the roles of some of the regulatory agencies were not characterized by deep involvement. Instead of in-depth regulatory supervision, there were general approaches according to which, for example, planned investments from development and construction plans were approved up to a specified level and as such included in the charges for network use. There are examples of less involvement by a regulatory agency during the initial phases of the introduction of regulation or during the initial regulatory periods. However, as the processes progressed and the regulatory agencies became increasingly involved in an increasing number of cases, in many cases the charges for network use dropped.

8) This nearly completely corresponds with the introduction of more complex regulatory approaches and methodologies of economic regulation, i.e. methods of the incentive regulation of activities. From the aforementioned, it was concluded that at the beginning it is necessary to define the responsibilities of the regulatory agency and the regulated entities as precisely as possible. Furthermore, under the newly arisen market circumstances, it is necessary to include and explain all the important parameters, influential values and market environment circumstances that are being introduced. It is especially important to start with simple regulatory approaches and methods and, as a rule, with short regulatory periods. Any of the potential uncertainties or hidden flaws in a regulatory approach, an incorrectly estimated influential parameter or a target economic index, the unforeseen negative consequences of the restructuring process in a dynamic market environment, or the ultimate consequences of any wrong decisions by the regulatory agency may lead either

ili naročito u slučajevima kada su državna tijela te profite oduzela energetskim subjektima. S druge strane, niski ili nedovoljno visoki iznosi naknada za korištenje mreža direktno ugrožavaju poslovanje energetskih subjekata, kvalitetu usluga i funkcija koje ti subjekti pružaju, a ako takvo stanje traje duže, onda i tehničko-tehnološke osobine same mreže i sustava.

Konačan zaključak u pogledu prethodnog bio je da bez obzira na uzroke, svaki problem i svaka posljedica prenosi se na korisnika ili krajnjeg kupca i postaju njegov problem, a obveza je i energetskog subjekta i regulatornog tijela da u reguliranom okružju te probleme i posljedice otklone. Najefikasnijim općim pristupom otklanjanja svih negativnih posljedica ocjenjuje se pragmatični pristup i postupanje, a ako je moguće i suradnja sve tri zainteresirane strane.

9) Poseban problem i izazov predstavlja regulacija mrežnih infrastrukturnih monopola, prijenosa i distribucije, te u svezi s tim usko povezani problem gdje i pod kojim uvjetima se osiguravaju pomoćne usluge sustava. Naročito se u segmentu pomoćnih usluga sustava mogu pojaviti dominantne pozicije i zlouporabe u još uvijek značajno integriranim sustavima, kada se poduzećima iz sustava ili grupe osiguravaju povoljniji uvjeti pristupa i korištenja pomoćnih usluga ili njihova plaćanja. U sprječavanju takvih situacija, štoviše njihova sankcioniranja, presudna je uloga regulatornih tijela.

Problem pomoćnih usluga i odgovornosti za njihovo osiguranje i pružanje usko je vezan s postojećim zakonodavnim i regulatornim okvirom, ili općenito pitanjem da li se na taj segment primjenjuje regulirani ili tržišni kontekst. U svakom slučaju, u svezi s tim segmentom najviše je pitanja i dilema. Pitanje je i kojoj djelatnosti iz dosadašnje integrirane strukture i jedinstvene tarife koja je uključivala sve djelatnosti i usluge pridijeliti odgovornost za osiguranje pomoćnih usluga, i kako te usluge naplatiti, kao dio odgovarajućih naknada ili zasebno. Neke zemlje taj problem razriješile su pridjeljujući obveze i funkcije osiguranja pomoćnih usluga operatorima prijenosnih i distribucijskih sustava, odnosno uvodeći ugovorne odnose po kojima tržišni sudionici i te usluge slobodno ugovaraju, osiguravaju i na kraju plaćaju. No, istaknuto je, da su takva rješenja i mehanizmi bili moguće tek nakon što je uspostavljena cjelovita funkcionalna i provedbena shema osiguravanja, tj. izvora i pridjeljivanja svake pojedinačne pomoćne usluge ili njene komponente, ali i uvjeta njihova eventualnog prekida i posljedica toga prekida. Činjenica je da su u nekim zemljama, a radi se o zemljama i energetskim gospodarstvima koja su u pravilu u ranim fazama procesa restrukturiranja, otvaranja

to very high or inadmissibly low charges for network use. High charges for network use would not only mean high costs for network users but would also pose a significant barrier to entry into the electricity market and development by those entities outside the current integrated national power systems. The unreasonably high profits of monopolies have further negative political and social consequences, even or especially in cases when government agencies have redirected these earnings away from the entities. On the other hand, low or insufficient charges for network use directly jeopardize the operations of entities, the quality of the services and functions provided by these entities and, if such conditions persist for extended periods, they may also jeopardize the technical and technological characteristics of the network and system.

The final conclusion in respect to the above is that regardless of the cause, each problem and consequence is shifted to the user or the final customers and becomes their problem. Both the entity and the regulatory agency should resolve these issues within the regulated environment and eliminate the consequences. The most efficient general approach to eliminating all such negative consequences is thought to be a pragmatic one, together with cooperation among all three interested parties, if possible.

9) A separate problem and challenge is the regulation of the network infrastructure monopolies, transmission and distribution and, closely connected to this, the issue of where and under which circumstances auxiliary system services should be provided. Especially in the segment of auxiliary services of the system, dominant positions and abuses may occur in systems that are still significantly integrated when enterprises from the system or groups are provided with more favorable conditions for accessing, using or paying for auxiliary services. In order to prevent such situations, moreover to penalize them, the role of the regulatory agencies is crucial.

The issue of auxiliary services and the responsibility for providing them are closely connected to the existing legislative and regulatory frameworks or, in general, to the question whether the regulated or market context should be applied to this segment. In any case, the most questions and dilemmas are associated with this segment. It is a question as to which activities from the current integrated structure and single tariff that included all the activities and services should be assigned responsibility for securing auxiliary services, and how should these services be charged, as a part of the corresponding charges or separately. Some countries have resolved this problem by assigning the obligations and functions for securing auxiliary services to the transmission and distribution system operators, or by introduc-

tržišta, odnosno razvoja i uspostave odgovarajućeg regulatornog okružja, pitanja i problemi uspostave cjelovitog sustava osiguravanja, korištenja, pridjeljivanja i plaćanja pomoćnih usluga sustava još uvijek samo naznačeni ili tek u ranim fazama rješavanja. U svakom slučaju neriješena pitanja i problemi u svezi s pomoćnim uslugama sustava znatno otežavaju razvidnost i efikasnost procesa otvaranja tržišta električne energije u svim njegovim ključnim sastavnicama, a naročito u pogledu osiguranja uvjeta za razvidan, nepristran i pravedan pristup mrežama i sustavima. Takvo stanje ima daljnje negativne posljedice po razvoj i uvođenje novih metoda regulacije i metodologija tarifnih sustava, što posljedično i regulatorno tijelo dovodi u puno teži položaj i ugrožava njegovu vjerodostojnost suočavajući ga s objektivno teškim problemom izbora pristupa i metodologije, ali i reakcijom energetskih subjekata i tržišnih sudionika.

U pravilu, stav je da u reguliranom kontekstu osiguranje i pružanje tih usluga treba biti jedna od funkcija i obveza operatora prijenosnog i distribucijskog sustava, koja je po unaprijed poznatim uvjetima, na razvidan, nepristran i nediskriminirajući način dostupna i pridjeljuje se korisnicima elektroenergetskih mreža i sustava. Zaključak je da razina cijena, odnosno tarifa za pomoćne usluge sustava treba biti troškovno utemeljena i razvidna u svim njegovim elementima. Tijekom rasprave istaknuto je da postoji i problem osiguranja određenih pomoćnih usluga od strane starih proizvodnih postrojenja. Kod postavljanja tržišnog modela o tom se mora voditi računa, naročito kod tržišnih modela koji podrazumijevaju mogućnost pristupa pojedinačnih proizvodnih postrojenja tržištu i njihove participacije na tržištu kao samostalnih tržišnih sudionika. Regulatorna tijela i operatori sustava o tim pitanjima i problemima moraju voditi računa u svim segmentima procesa definiranja tržišnog modela, regulatornog okvira i modela, provedbenih procedura, a ako je kontekst pomoćnih usluga sustava regulirani, onda i metodologiji utvrđivanja tarifnih stavki i proceduri ugovaranja i osiguravanja pomoćnih usluga sustava.

**10)** Ključnim ciljevima regulacije energetskih djelatnosti, naročito prijenosa i distribucije električne energije smatraju se uspostava nepristranog i razvidnog pristupa mreži, pokriće opravdanih troškova poslovanja, nastojanja da se unaprijedi efikasnost sektora i/ili da se sektor učini privlačnim za nove investicije, odnosno ulaganja. Odgovarajući izvori financiranja mogu se osigurati bilo neposredno kroz naknade za priključak i korištenje mreža, bilo kroz odgovarajuće poticajne uvjete i povrate na investicije, odnosno od i imovinu energetskog subjekta. Postupke i

ing contractual relations on the basis of which the market participants freely contract, provide and at the end pay for these services. However, it has been pointed out that such solutions and mechanisms are only possible after the entire functional and implementation scheme is established, i.e. the source and assignment of each individual auxiliary service or component thereof, as well as the conditions for their eventual termination and the consequences of such termination. The fact is that in some countries, mainly countries and electrical energy economies which are in the early phases of restructuring, market opening and developing an appropriate regulatory environment, the issues and problems of the establishment of the overall system for the provision, use, allocation and payment of auxiliary services are still only on paper or in the early phases of solution. In any case, the unresolved issues and problems in connection with auxiliary system services significantly diminish the transparency and efficiency of the opening of electricity markets in all the key elements, especially regarding the providing of the conditions for the transparent, nondiscriminatory and fair access to networks and systems. Such a situation has further negative consequences upon the development and introduction of new regulatory methods and methodologies of the tariff systems, which consequently place the regulatory agency in a far more difficult position and threaten its credibility, confronting it with the difficult problem of choosing an approach and methodology, as well as the reactions of the entities and market participants.

In principle, the position is that in the regulated context, providing these services should be one of the functions and obligations of the transmission and distribution system operators, which, under predetermined conditions should be available and assigned to users of electricity networks and systems in a transparent, nondiscriminatory and non-discriminatory manner. The conclusion is that the level of prices, i.e. tariffs for the auxiliary services of a system, should be cost-based and transparent in all elements. During the discussion, it was emphasized that there is also the problem of securing certain auxiliary services from the old power-generation facilities. When setting up a market model, this must be taken into account, especially with market models that include the option of access by individual power-generation facilities to the market, and their status as independent market participants. The regulatory agencies and system operators must take these issues and questions into account in all the segments of the process of the definition of a market model, regulatory framework and model, and implementation procedures. If the context of auxiliary system services is regulated, this also means taking into account the methodology for establishing tariff items and procedures for the contracting and providing of auxiliary system services.

metode regulacije i metodologije tarifnih sustava u tom pogledu nužno je stalno dograđivati i unaprjeđivati. U tom pogledu, regulatorno tijelo ima primarni zadatak, ali s obzirom na to da opskrba električnom energijom ostaje i nadalje aktivnost visokog socijalnog i gospodarskog značenja, u rad na predmetnoj problematici trebaju biti uključena poduzeća iz energetskog sektora, tijela državne uprave i druge državne institucije, stručna i ostala javnost, te organizacije za zaštitu interesa potrošača, sindikati i financijske institucije. Sve više je dokaza u prilog opće važnosti koje predmetnoj problematici posvećuju sve navedene stranke.

**11)** Regulatorno tijelo treba imati kontrolu nad svim segmentima regulacijskog razdoblja. Naročito se to odnosi na pripremno razdoblje u kojem bi regulatorno tijelo trebalo biti aktivno uključeno, uz regulirani subjekt. Odnosi se to na pregled ulaznih podataka, podloga i parametara koje se koriste, njihovu obradu, kao i rokove u kojima se pojedini segment pripremne faze za uvođenje metode regulacije mora provesti. U prilog tome govore i odgovarajuća iskustva nekih zemalja.

**12)** U prethodnom kontekstu, u socijalnom, političkom i gospodarskom smislu u svezi sa stabilnošću i sigurnošću opskrbe svakako je dobro izbjegavati velike i nagle skokove u promjenama cijena, nepredvidive ili nenajavljene promjene cijena. U pogledu mogućnosti reguliranih energetskih subjekata da razumiju, prilagode se i provedu odgovarajući regulatorni pristup i prilagode poslovanje novom sadržaju koji su iskazani kroz postupke i metode regulacije, svakako je nužna suradnja regulatornog tijela i reguliranih subjekata. Suradnja je i ključni preduvjet potpunog razumijevanja procesa i sadržaja definicije i uspostave određenog okvira i postupka regulacije, i kroz proces utvrđivanja i donošenja odgovarajućih tarifnih stavki, a time i njihova prihvaćanja i dobre provedbe. Uzimajući u obzir i sve druge moguće utjecaje, npr. socijalni i/ili politički, nije naodmet ustvrditi da se nerijetko postupa pragmatično, nastojeći odvagnuti i nastojeći valorizirati doprinos svakog od tih mogućih utjecaja ili ograničavajućih elemenata.

Od regulatornih tijela traži se kvalitetan i efikasan sustav nadzora nad tržištem električne energije, pogotovo sprječavanje ili čak sankcioniranje situacija u kojima se u tzv. integriranim sustavima sredstva prelijevaju iz monopolnih djelatnosti u tržišne djelatnosti, osiguravajući tržišnim djelatnostima znatnu neopravdanu i neprihvatljivu prednost u odnosu na druge tržišne sudionike u tržišnoj utakmici, što je ujedno i direktan oblik zlouporaba neopravdane tržišne pozicije ili snage. Navedeni su i konkretni slučajevi u kojima su u takvim si-

**10)** The key goals of the regulation of energy activities, especially the transmission and distribution of electricity, are to establish nondiscriminatory and transparent access to the network, cover justified operational costs, attempt to improve the efficiency of the sector and/or make the sector attractive for new investments. Suitable sources of financing can be secured either directly through charges for connection to the network, network use or through suitable incentive conditions and returns on investments, i.e. from the assets of the entities. Procedures and methods for the regulation and methodology of the tariff systems must be constantly updated and improved. In this regard, the regulatory agency has the primary task. However, since the supplying of electricity continues to remain an activity of great social and economic significance, enterprises from the energy sector, government administrative agencies, other government institutions, professionals, the general public, organizations for protecting consumer interests, unions and financial institutions should be included in working on this issue. There is increasing evidence of the general importance afforded to this issue by all the aforementioned parties.

**11)** The regulatory agency must have control over all the segments of the regulatory period. This especially refers to the preparatory period in which the regulatory agency should be actively involved, together with the regulated entity. It concerns a review and processing of the input data, bases and parameters used as well as the periods within which the separate segments of the preparatory phase for the implementation of a regulatory method must be completed. The corresponding experiences of some countries underscore this point.

**12)** In the aforementioned context, in the social, political and economic sense, regarding the stability and safety of supply, it is indeed good to avoid large and sudden price changes and unforeseen or unannounced price changes. Regarding the abilities of the regulated energy entities to understand, adapt to and implement the suitable regulatory approach and adjust operations to the new content expressed through the regulatory procedures and methods, cooperation between the regulatory agency and the regulated entities is certainly essential. Cooperation is also a key prerequisite for completely understanding the process and the contents of the definitions and the establishment of certain frameworks and regulatory procedures, both through the process of the determination and adoption of certain tariff items, and through their acceptance and correct implementation. Taking into account any other possible influences, e.g. social and/or political, it is worth mentioning that a pragmatic approach, in which it is attempted to weigh and evaluate the contribution of each of these potential influences or limiting elements, is often employed.

tuacijama regulatorna tijela postupala tako da se umanjila, ili čak oduzela odgovarajući dio prihoda od integriranog poduzeća, i to od segmenta tržišnih djelatnosti, i vratila ga u segment monopolnih, odnosno djelatnosti s obvezama javnih usluga iz kojeg su i bili neopravdano uzeti. U svakom slučaju, dok postoje dvije paralelne komponente tržišta, regulirana i liberalizirana, odnosno tržišna, regulatorno tijelo ima striktnu obvezu provjeravati razvidnost odvajanja pripadajućih računa i prihoda, a nerijetko i pravo da određene oblike ponašanja i prekršaja i jače sankcionira. Čest je slučaj da regulatorno tijelo ima pravo, utemeljeno na zakonu, samo provesti odgovarajući revizorski nadzor, ili taj nadzor zatražiti od nezavisnih revizora.

**13)** Okrugli stol je raspravio i pitanja strukture naknada za korištenje prijenosne, odnosno distribucijske mreže. Istaknuta je važnost primjene principa da struktura i razina naknada za korištenje mreža odražavaju strukturu troškova za elemente energije i snage, tj. kapaciteta, prema i za koje se utvrđuju. Poglavito je element snage i njegovo vrednovanje važan u strukturi tarifnih stavki, tj. naknada za priključak, za korištenje prijenosne i distribucijske mreže, i naknada za pomoćne usluge sustava. Važnost elementa kapaciteta ogleda se i u vrednovanju u svezi s mehanizmima pridjeljivanjem, korištenjem i plaćanjem odgovarajućih prekograničnih kapaciteta, ili utvrđivanjem odgovornosti, odnosno postupcima rješavanja zagušenja u prijenosnoj i distribucijskoj mreži.

**14)** U nekim zemljama proces uvođenja novog regulatornog pristupa i primjene novih metodologija ekonomske regulacije koji u pravilu uključuju parametre valorizacije i poticanja učinkovitosti poslovanja reguliranog energetskog subjekta, a nerijetko i odgovarajuće opće makroekonomske indekse za valorizaciju i pokriće adekvatnih rizika poslovanja i ulaganja, rezultirao je u smanjenju naknada za korištenje mreža. Međutim, nije realno očekivati da bi se takav kontekst ponovio u većini drugih zemalja, pogotovo ne u zemljama u kojima su cijene električne energije bile pod jakom socijalnom i političkom kontrolom i u pravilu vrlo niske. Štoviše, u tim zemljama izražena je potreba za novim velikim ulaganjima u održavanje, rekonstrukciju i izgradnju mreža. Razdvajanje i izdvajanje energetskih djelatnosti iz dosadašnjih vertikalno integriranih elektroenergetskih struktura proizvodnje, prijenosa, distribucije i opskrbe električnom energijom, otvaranje tržišta električne energije i pojava novih sudionika na tržištu električne energije, tu potrebu samo su još više naglasili. Nije rijedak slučaj sve češće iskazanih uvjerenja da bez dobrih i efikasnih infrastrukturnih prijenosnih i distribucijskih mreža i sustava ne može biti govora o razvoju efikasnog tržišta električne energije.

The regulatory agencies are required to provide a quality and efficient system of supervising the electricity market, especially to prevent or penalize situations in which funds flow from monopoly activities into market activities in the so-called integrated systems, which affords businesses with market operations a significant unfair and unacceptable advantage over other market participants in market competition, and is a direct form of the abuse of an inequitable market position or power. Specific cases were mentioned in such situations when the regulatory agencies acted to reduce or even confiscate the corresponding portion of the revenues from an integrated company from the segment of market activities and direct them back to the monopoly segment, i.e. the activities having the public service obligation from which they had been unfairly taken. In any case, as long as there are two parallel components of the market, regulated and liberalized, the regulatory agency has the strict obligation to verify the transparency of the separation of the corresponding invoices and revenues, and not infrequently the right to penalize certain forms of behavior and violations severely. The regulatory agency frequently only has the right, pursuant to the law, to conduct a suitable audit or request to have such an audit performed by independent auditors.

**13)** The Round Table Discussion also included questions regarding the structure of charges for the use of a transmission or distribution network. The importance was stressed of applying the principle that the structure and level of charges for network use should reflect the structure of the costs of the elements of energy and power, i.e. the capacities according to and for which they are determined. The element of power and its valuation are particularly important for the structure of the tariff items, i.e. charges for connection, the use of the transmission and distribution networks and auxiliary system services. The importance of the capacity elements is reflected in the evaluation in connection with mechanisms for capacity allocation, the use and charges for cross-border capacities, or determination of the responsibilities, i.e. the procedures for managing congestion in the transmission and distribution networks.

**14)** In some countries, the process of introducing a new regulatory approach and the application of new methodologies of economic regulation, which as a rule include the parameters for the evaluation and increased effectiveness of the operations of a regulated power entity and not infrequently the corresponding general macroeconomic indices for the evaluation and coverage of adequate risk operations and investments, have resulted in lowered charges for network use. However, it is not realistic to expect such a context to be repeated in the majority of other countries, especially those where electricity prices

Na spomenuti kontekst ulaganja u održavanje, rekonstrukciju i izgradnju nacionalnih elektroenergetskih mreža, odnosno izgradnje novih visokonaponskih prijenosnih prekograničnih poveznica s drugim zemljama i sustavima sve važniji utjecaj ima regionalni i širi multinacionalni kontekst tržišta i razmjena električne energije. Opća je pojava da prekogranična trgovanja i razmjene energije vrlo brzo rastu, zbog čega su za tranzite i prekogranične razmjene energije uvedeni i primjenjuju se novi opće prihvaćeni kompenzacijski i alokacijski mehanizmi. Isti se već jednoznačno primjenjuju u kontekstu internog europskog tržišta električne energije. Nadalje, prihodi ostvareni prekograničnim razmjenama moraju se tretirati na razvidan i nepristran način. Međutim, unatoč nastojanju da se razvije i uspostavi efikasan, razvidan, nepristran i pravedan, u konačnici i lako provediv sustav i mehanizam, za neke elektroenergetske sustave i nadalje ostaje problem načina utvrđivanja i alokacije troškova za visoke gubitke električne energije. Isto vrijedi i u pogledu adekvatnog dijela pomoćnih usluga sustava. Naime, radi se o onom dijelu dodatnih gubitaka električne energije u nacionalnoj elektroenergetskoj mreži i dijelu dodatnih pomoćnih usluga sustava koji nastaju zbog prolaza ili kružnih tokova energije iz međunarodnih, tj. prekograničnih razmjena energije. Opći je stav da europsko energetsko zakonodavstvo, tj. odgovarajuće direktive i uredbe EU u tom pogledu predstavljaju adekvatan zakonodavni okvir za postupanje svih regulatornih tijela.

15) Poseban je problem načina pristupa i dobivanja informacija i podatak koje s jedne strane regulatorno tijelo može tražiti i traži od reguliranih subjekata, a koje s druge strane ti regulirani subjekti mogu i žele dati ili daju regulatornom tijelu. U svakom slučaju razlike, tj, asimetrija informacija, u tom pogledu uvijek su prisutne. Zaključak je da je u svakom slučaju, bilo u pogledu zadovoljavajućeg rješenja, bilo barem dobre ravnoteže između regulatornog tijela i reguliranih energetskih subjekata najbolje i najefikasnije odabrati pragmatična rješenja, po mogućnosti zasnovana na dostupnoj najboljoj i najefikasnijoj međunarodnoj praksi i benchmarku. Prethodno gotovo u potpunosti vrijedi i u pogledu procesa i prakse regulatornog ili revizorskog nadzora.

16) Posebno je uočena i istaknuta mogućnost i potreba šire, tj. regionalne elaboracije i rasprave problema sadržaja i forme regulacije, regulatornih pristupa i politike, strukture i sadržaja tarifnih metodologija i samih tarifa, utjecajnih parametara i pokazatelja, naročito ekonomskih i političkih, usporednih *(benchmark)* pristupa i analiza, te svakako veće suradnje i transfera znanja i iskustava.

have been under rigorous social and political control and, as a rule, very low. Moreover, in these countries there is a marked need for major new investments in maintenance, reconstruction and network construction. The separation of energy activities from the heretofore vertically integrated structures of the generation, transmission, distribution and supply of electricity, the opening of the electricity markets and the appearance of new participants on the electricity market further underscore this need. Opinions are frequently voiced that the development of an efficient electricity market is not feasible without a good and efficient infrastructure for the transmission and distribution networks and systems.

In this context, investments in the maintenance, reconstruction and construction of national electrical energy networks or in the construction of new high voltage transmission cross-border connections with other countries and systems have an increasing impact upon the regional and broader multinational context of the markets and the exchange of electricity. The cross-border commerce and exchange of energy is generally growing very rapidly, due to which new commonly accepted compensation and allocation mechanisms have been introduced and applied for the transit and cross-border exchange of energy. Such mechanisms are already being applied uniformly within the context of the internal European electricity market. Furthermore, the revenues from cross-border exchanges must be treated in a transparent and nondiscriminatory manner. However, despite attempts to develop and establish an efficient, transparent, nondiscriminatory, just and, in the final analysis, easily applicable system and mechanism, some energy systems are still confronted with the problem of how to determine and allocate expenditures for high losses of electricity. This concerns the share of the additional electricity losses in the national electrical energy network and the share of the additional auxiliary system services that occur due to transit or circular flows from international, i.e. cross-border, energy exchanges. The general position is that the European energy legislation, i.e. the corresponding directives and regulations of the EU in this respect, represents an adequate legislative framework for the operations of all the regulatory agencies.

15) There is a specific problem regarding the manner of accessing and obtaining information and data which a regulatory agency can and does require from regulated entities, and which these regulated entities can and want to provide or do provide to the regulatory agency. In any case, these differences, i.e. information asymmetry, are always present in this regard. The conclusion is that in order to obtain a satisfactory solution or at least a good balance between the regulatory agency and the regulated en-

# 5 ZAKLJUČAK

Okrugli stol o ulozi regulatornog tijela u donošenju tarifnih sustava organiziran je kao mjesto susreta i rasprave eksperata i direktnih sudionika, odnosno zainteresiranih strana u regulacijskom procesu, od predstavnika regulatornih tijela, stručne i znanstvene javnosti, do predstavnika reguliranih subjekata. Okrugli stol bio je vrlo uspješan i u potpunosti je opravdao razloge organiziranja, ponudivši dobru elaboraciju problematike i sadržaja regulacije energetskih djelatnosti, organizacije i nadzora tržišta električnom energijom, a posebno i ciljano uloge regulatornog tijela u donošenju tarifnih sustava. Konačno, Okrugli stol ponudio je i niz odgovora, ali i što je još važnije, sudionike je ili uveo u predmetnu problematiku i ukazao im na opću prisutnost sličnih pitanja i dilema u svim zemljama, od članica EU do zemalja koje će tek postati članice EU, ili im dao odgovore na pitanja i dileme s kojima su došli na Okrugli stol. Bez obzira na različita iskustva i dinamiku procesa, Okrugli stol je pomogao da se identificira i komentira niz izazova i problema s kojima se suočavaju sva regulatorna tijela, ali i sva regulirana poduzeća i energetski subjekti, bez obzira na sustave iz kojih dolaze i kontekst u kojem su nastala i u kojem su se razvijala. Također, uočena je mogućnost i potreba za stalnom elaboracijom i raspravom problema sadržaja i forme regulacije, regulatornih pristupa i politike, strukture i sadržaja tarifnih metodologija i samih tarifa, utjecajnih parametara i pokazatelja, naročito ekonomskih i političkih, usporednih *(benchmark)* pristupa i analiza, te svakako veće suradnje i transfera znanja i iskustava.

Zbog svega prethodnog, cilj i svrha ovog članak bili su širu stručnu i znanstvenu javnost izvijestiti o rezultatima, odnosno tijeku i zaključcima tog Okruglog stola, te eventualno potaći stručnu i znanstvenu raspravu o izloženoj problematici, pa čak potaći organizaciju novih okruglih stolova i rasprava o izloženim pitanjima, problemima, sadržajima, ali i izazovima regulacije energetskih djelatnosti.

ergy entities, it is best and most efficient to choose pragmatic solutions, if possible based upon the best available and most efficient international practices and benchmarks. The aforementioned applies in its entirety to the processes and practices of regulatory or audit supervision.

16) We have especially noted and emphasized the possibility and necessity for the broader regional elaboration and discussion of the problems of the contents and forms of regulations, regulatory approaches and policies, the structures and contents of tariff methodologies and the tariffs themselves, influential parameters and indices (especially economic and political), benchmark approaches and analysis, together with greater cooperation and the transfer of knowledge and experiences.

# 5 CONCLUSION

The Round Table Discussion on the role of the regulatory agency in the adoption of tariff systems was organized as place of meeting and discussion among experts and direct participants, i.e. interested parties in the regulatory process, from representatives of the regulatory agencies, the professional and scientific public, to representatives of the regulated entities. The Round Table was highly successful and completely justified the reasons for its organization, providing good elaboration of the issues and contents of the regulations on energy operations, the organization and supervision of the electricity market and, particularly, the planned role for the regulatory agency in the adoption of the tariff systems. Finally, the Round Table Discussion provided a series of answers but, more importantly, introduced the participants to the issue under discussion and demonstrated to them that similar questions and dilemmas are generally present in all countries, from the member countries of the EU to the countries that will become members of the EU, or provided them with answers to the questions and dilemmas that they brought with them to the Round Table. Regardless of the various experiences and process dynamics, the Round Table Discussion helped identify and comment on a series of challenges and problems confronted by all regulatory agencies, as well as all regulated enterprises and energy entities, regardless of the systems from which they come and the context in which they originated and developed. Furthermore, the possibility and need were perceived for the ongoing elaboration and discussion of the problems of the content and form of regulation, regulatory approaches and policies, the structure and content of tariff methodologies and the tariffs themselves, the influential parameters and indices (especially economic and political), benchmark approaches and analysis, and certainly

greater cooperation and the transfer of knowledge and experience.

Due to all the aforementioned, the goal and purpose of this article were to inform the general professional and scientific public about the results and conclusions of this Round Table Discussion, eventually stimulate expert and scientific discussion about the issues presented, and even stimulate the organization of new round tables and discussions on the questions, problems, contents but also the challenges of the regulation of energy operations.

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Uredništvo primilo rukopis:
2007-07-30

Prihvaćeno:
2007-08-13

Manuscript received on:
2007-07-30

Accepted on:
2007-08-13

# ENERGIJA

JOURNAL OF ENERGY

# ENERGIJA

05/07

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Devizni račun:
Zagrebačka banka broj: 2000006299

Grafičko uređenje omota – mr. sc. Kažimir Vrankić, Zagreb
Grafičko uređivanje – Bestias dizajn d.o.o., Zagreb
Tisak – Intergrafika d.o.o, Zagreb

Naklada – 1 500 primjeraka
Zagreb, 2007

Godište 56(2007)
Broj 5., str. 521–636

Oglasi su veličine jedne stranice. Cijena oglasa je 3 000 kn bez PDV (22%).

# ENERGIJA

**PUBLISHED BY**
Hrvatska elektroprivreda d.d., Zagreb

**PUBLISHER'S REPRESENTATIVE**
Ivan Mravak, MSc

**CO-PUBLISHED BY**
Univesity of Zagreb, Fakulty of Electrical Engineering and Computing
Ministry of Economy, Labour and Entrepreneurship

**SUPPORTED BY**
Ministry of Science, Education and Sport

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e-mail: goran.slipac@hep.hr; slavica.barta@hep.hr;
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Appears 6 times a year.
Annual subscription fee excl. VAT (22 %):
– for individual subscribers HRK 250
– for companies HRK 400
– for students HRK 60
Number of gyro account with Zagrebačka Banka:
2360000-1400129978

Annual subscription fee for the overseas: USD 95.
Number of foreign currency account with Zagrebačka Banka:
2000006299

Cover design – Kažimir Vrankić, MSc, Zagreb
Graphic layout – Bestias Dizajn d.o.o., Zagreb
Printed by – Intergrafika d.o.o., Zagreb

Circulation – 1,500 copies
Zagreb, 2007

Volume 56(2007)
No 5., pp. 521–636

Ads are the size of page. The price of an ad is HRK 3 000 excl. VAT (22%).


# SADRŽAJ



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Časopis je ubilježen u Ministarstvu znanosti, obrazovanja i sporta pod brojem 161 od 12.11.1992.

Časopis je indeksiran u sekundarnom bibliografskom izvoru INSPEC – The Institution of Electrical Engineering, England.

The magazine is registered with the Ministry of Science, Education and Sport under No. 161 since 12.11.1992.

The magazine is indexed with the secondary reference source of INSPEC – The Institution of Electrical Engineering, England.

# UREĐIVAČKA POLITIKA

Časopis Energija znanstveni je i stručni časopis s dugom tradicijom više od 50 godina. Pokriva područje elektroprivredne djelatnosti i energetike. Časopis Energija objavljuje izvorne znanstvene i stručne članke širokoga područja interesa, od specifičnih tehničkih problema do globalnih analiza procesa u području energetike.

U vrlo širokom spektru tema vezanih za funkcioniranje elektroprivredne djelatnosti i općenito energetike u tržišnim uvjetima i općoj globalizaciji, časopis ima poseban interes za specifične okolnosti ostvarivanja tih procesa u Hrvatskoj i njezinu regionalnom okruženju. Funkcioniranje i razvoj elektroenergetskih sustava u središnjoj i jugoistočnoj Europi, a posljedično i u Hrvatskoj, opterećeno je mnogobrojnim tehničko-tehnološkim, ekonomskim, pravnim i organizacijskim problemima. Namjera je časopisa da postane znanstvena i stručna tribina na kojoj će se kritički i konstruktivno elaborirati navedena problematika i ponuditi rješenja.

Časopis je posebno zainteresiran za sljedeću tematiku: opća energetika, tehnologije za proizvodnju električne energije, obnovljivi izvori i zaštita okoliša; korištenje i razvoj energetske opreme i sustava; funkcioniranje elektroenergetskoga sustava u tržišnim uvjetima poslovanja; izgradnja elektroenergetskih objekata i postrojenja; informacijski sustavi i telekomunikacije; restrukturiranje i privatizacija, reinženjering poslovnih procesa; trgovanje i opskrba električnom energijom, odnosi s kupcima; upravljanje znanjem i obrazovanje; europska i regionalna regulativa, inicijative i suradnja.

Stranice časopisa podjednako su otvorene iskusnim i mladim autorima, te autorima iz Hrvatske i inozemstva. Takva zastupljenost autora osigurava znanje i mudrost, inventivnost i hrabrost, te pluralizam ideja koje će čitatelji časopisa, vjerujemo, cijeniti i znati dobro iskoristiti u svojem profesionalnom radu.

# EDITORIAL POLICY

The journal Energija is a scientific and professional journal with more than a 50-year tradition. Covering the areas of the electricity industry and energy sector, the journal Energija publishes original scientific and professional articles with a wide area of interests, from specific technical problems to global analyses of processes in the energy sector.

Among the very broad range of topics relating to the functioning of the electricity industry and the energy sector in general in a competitive and globalizing environment, the Journal has special interest in the specific circumstances in which these processes unfold in Croatia and the region. The functioning and development of electricity systems in Central and South Eastern Europe, consequently in Croatia too, is burdened with numerous engineering, economic, legal and organizational problems. The intention of the Journal is to become a scientific and professional forum where these problems will be critically and constructively elaborated and where solutions will be offered.

The Journal is especially interested in the following topics: energy sector in general, electricity production technologies, renewable sources and environmental protection; use and development of energy equipment and systems; functioning of the electricity system in competitive market conditions; construction of electric power facilities and plants; information systems and telecommunications; restructuring and privatization, re-engineering of business processes; electricity trade and supply, customer relations; knowledge management and training; European and regional legislation, initiatives and cooperation.

The pages of the Journal are equally open to experienced and young authors, from Croatia and abroad. Such representation of authors provides knowledge and wisdom, inventiveness and courage as well as pluralism of ideas which we believe the readers of the Journal will appreciate and know how to put to good use in their professional work.

# UVOD
# INTRODUCTION

**Dragi čitatelji,**
u rukama Vam je novi broj časopisa Energija koji, kao i do sada, donosi niz aktualnosti iz područja tržišta električne energije te pojedinih specijalističkih područja u elektrotehnici. U svijetu, ali i u Hrvatskoj, dominiraju teme vezane uz razvoj i izgradnju energetskih infrastrukturnih sustava, bilo da se radi o plinskom ili elektroenergetskom sustavu. Stručna javnost osim o ovim važnim aspektima energetskih i elektroenergetskih sustava razmatra i pitanja regulacije energetskih djelatnosti, odnosno regulatorne politike koja treba omogućiti uspostavu tržišta umreženih energenata; električne energije i prirodnog plina.

U ovom broju časopisa Energija, objavljujemo članke koji su na neposredan ili posredan način vezani uz regulaciju energetskih djelatnosti, a isto tako i članke iz pojedinih specijalističkih područja elektrotehnike:

– Uloga regulatornog tijela u donošenju tarifnih sustava – okrugli stol – prikaz i zaključci
– Regulatorna politika i njen utjecaj na planove razvoja i izgradnje energetskih subjekata koji obavljaju regulirane djelatnosti
– Numerički proračun niskofrekvencijskih elektromagnetskih prijelaznih pojava u energetskim transformatorima
– Dijagnostički pregled raspada elektroenergetskog sustava na otoku rodosu
– Baza podataka relejne zaštite.

U prvom članku su prikazani zaključci s Okruglog stola Hrvatskog ogranka CIGRE Studijskog odora C5 – Tržište električnom energijom i regulacija. Naime, reforma elektroenergetskog sektora podrazumljeva i reformu tarifnog sustava koja bi se trebala provesti početkom sljedeće godine i u ovom članku dani su vrlo zanimljivi komentari zainteresiranih strana u hrvatskom elektroenergetskom sektoru, ali i relevantnih eksperata iz europskih regulatornih tijela i zemalja s višegodišnjim iskustvom u ekonomskoj regulaciji, bilo da se radi o dugogodišnjim članicama EU, ili zemljama koje su tek nedavno postale članice EU.

**Dear Readers,**
You are holding the most recent issue of the journal *Energija*, which continues to present news about the electricity markets and individual specialized fields in electrical engineering. In the international community as well as Croatia, there is major interest in the development and construction of energy infrastructure systems, both gas or electricity. The professional public is also concerned with questions regarding the regulation of energy activities and regulatory policies for the purpose of establishing markets for networked energy.

In this issue of the journal, we are presenting articles that are directly or indirectly connected with the regulation of energy activities and articles from individual specialized areas of electrical engineering:

– The Role of the Regulatory Agency in the Adoption of Tariff Systems: Round Table Discussion – Report and Conclusion
– Regulatory Policy and Its Impact on the Development and Construction Plans of Regulated Energy Entities
– The Numerical Calculation of Low Frequency Electromagnetic Transient Phenomena in Power Transformers
– Diagnostic Review of a Blackout in Rhodes
– Relay Protection Database

The first article presents conclusions from the Round Table Discussion on the Role of the Regulatory Agency in the Adoption of Tariff Systems organized by the Croatian National Committee of CIGRE – C5 – Electricity Markets and Regulation. Reform of the electricity sector also includes reform of the tariff system, which should be implemented early next year. This article provides valuable commentaries by interested parties in the Croatian electricity sector as well as relevant experts from the European regulatory bodies and countries with many years of experience in economic regulation, long-time members of the EU as well as countries that have recently become members.

U postupku davanja suglasnosti na visinu tarifnih stavki, Hrvatska energetska regulatorna agencija daje suglasnost na trogodišnje planove razvoja i izgradnje prijenosne, odnosno distribucijske mreže. Tako se u drugom članku daju komentari na različite aspekte regulatorne politike, koja u velikoj mjeri može utjecati na razvoj prijenosne i distribucijske mreže te na poslovanje subjekata koji obavljaju regulirane djelatnosti.

Model transformatora primjenjiv u niskofrekvencijskim elektromagnetskim prijelaznim pojavama s frekvencijama reda veličine približno 1 kHz, prikazan je u trećem članku. U radu se polazi od matematičkog i analitičkog modela, a zatim je zbog ograničenja analitičkog modela u analizu uveden numerički pristup rješavanja krutih diferencijalnih jednadžbi koje opisuju prijelaznu pojavu. Razvijeni algoritam može se uspješno koristiti u ostalim niskofrekvencijskim prijelaznim pojavama gdje je glavni predmet analize nelinearni karakter transformatora.

Članak skupine autora iz Grčke daje sažet prikaz i analizu raspada elektroenergetskog sustava otoka Rodosa. Opisani i dijagnosticirani raspad elektroenergetskog sustava vrlo je zanimljiv s obzirom da se radi o izoliranom sustavu u kojemu se sukcesivno događa nekoliko poremećaja različitih uzroka i posljedica.

Posljedni članak obrađuje temu baze podataka, u ovom slučaju podataka o relejnoj zaštiti. U dobro strukturiranom članku daje se model korištenja baze svih relevantnih podataka vezanih uz relejnu zaštitu i to na način da se koristi relativno lako dostupan komercijalni program. Posebna značajka ovog modela upravljanja bazom podataka je njegova jednostavnost, što znači da potrebna razina znanja o tehnikama baza podataka te načinu pretraživanja i čuvanja podataka ne mora biti visoka.

Članke u ovom broju časopisa Energija potpisuje dvanaest autora iz sveučilišne zajednice, ali i iz prakse, što je, vjerujem, rezultiralo i kvalitetnim člancima.

**Glavni urednik**
**mr. sc. Goran Slipac**

As part of the procedure for authorizing the amounts of tariff items, the Croatian Energy Regulatory Agency authorizes three-year development and construction plans for transmission and distribution networks. The second article provides commentaries on various aspects of the regulatory policy, which can have a considerable impact upon the development of the transmission and distribution networks, as well as the operations of the regulatory bodies.

In the third article, a transformer model is presented that is applicable to low frequency electromagnetic transient phenomena of up to 1 kHz. The article first presents analytical and mathematical models. Due to the limitations of the analytical model, a numerical approach is introduced for the solution of the stiff differential equations that describe the transient phenomena. The algorithm developed can be used successfully in other low frequency transient phenomena where the main subject of analysis is the nonlinear character of the transformer.

An article by a group of authors from Greece summarizes and analyzes a blackout that occurred in the electrical energy system on the island of Rhodes. The description and diagnosis of the system blackout is very interesting because it concerns an isolated system in which there were successive perturbations with various causes and consequences.

The last article concerns the topic of databases, in this case data on relay protection. This well-structured article presents a relay protection data model using the easily obtainable Microsoft Access Database Program. A particular characteristic of this model of database management is its simplicity, which means that the required level of user knowledge regarding database techniques, searches and data storage need not be high.

The articles in this issue of the journal *Energija* are signed by twelve authors from the university and energy bussines.

**Editor-in-Chief**
**Goran Slipac, MSc**

# ULOGA REGULATORNOG TIJELA U DONOŠENJU TARIFNIH SUSTAVA: OKRUGLI STOL – PRIKAZ I ZAKLJUČCI

# THE ROLE OF THE REGULATORY AGENCY IN THE ADOPTION OF TARIFF SYSTEMS: ROUND TABLE DISCUSSION – REPORT AND CONCLUSION

Dr. sc. Mićo Klepo, Hrvatska energetska regulatorna agencija, Koturaška cesta 51, 10000 Zagreb, Hrvatska

Krajem 2006. godine Hrvatska energetska regulatorna agencija donijela je metodologije za izračun tarifa za djelatnosti proizvodnje, prijenosa, distribucije i opskrbe električnom energijom, koje su do sada bile komponente jedinstvene tarife za integrirani sustav djelatnosti proizvodnje, prijenosa, distribucije i opskrbe električnom energijom. Sukladno zakonskoj obvezi razdvajanja navedenih djelatnosti, izraženih i kroz pristup spomenutim metodologijama tarifnih sustava, u tijeku su poslovi vezani uz izračun i donošenje tarifnih stavki za navedene energetske djelatnosti. Primjenom spomenutih metodologija, odnosno donošenjem i stupanjem na snagu novih tarifnih stavki elektroenergetski sektor i elektroenergetsko gospodarstvo Republike Hrvatske ući će u probno regulatorno razdoblje. Stoga je i za regulatorno tijelo, za predstavnike reguliranih djelatnosti, jednako tako i za stručnu javnost od velike važnosti i pomoći bilo raspraviti neka pitanja i dileme iz predmetne problematike, i to upravo na skupu s predstavnicima raznih zainteresiranih strana.

In late 2006, the Croatian Energy Regulatory Agency adopted methodologies for the calculation of tariffs for the activities of the generation, transmission, distribution and supply of electricity, which until now have been components of a single tariff for an integrated system of the activities of the generation, transmission, distribution and supply of electricity. Pursuant to the legal obligations to separate these activities, as also expressed through the approach of the cited methodologies of the tariff systems, activities are in progress in reference to the calculation and adoption of tariff items for the aforementioned fundamental energy activities. With the application of the cited methodologies, i.e. the adoption and coming into force of the new tariff systems of the electricity sector and the electricity sector of the Republic of Croatia, a new trial regulatory period will be entered. Therefore, for the regulatory agency, representatives of the regulated entities, and professional public, discussion of several questions and dilemmas from this area at a meeting among representatives of various interested parties was considered to be of great importance and benefit.

Ključne riječi: energetsko regulatorno tijelo, ekonomska regulacija, metoda priznatih troškova, metodologija tarifnog sustava, regulacija stopom povrata

Key words: economic regulation, energy regulatory agency, method of recognized costs, regulation of the rate of return, tariff system methodology

# 1 UVOD

Na inicijativu SO C5 – Tržište električnom energijom i regulacija, IO HRO CIGRÉ, u Zagrebu je 15. svibnja 2007. godine održan Okrugli stol – Uloga regulatornog tijela u donošenju tarifnih sustava.

Okrugli stol organiziran je sa svrhom i ciljem da predstavnici regulatornih tijela i predstavnici reguliranih subjekata uz prisutnost stručne javnosti izlože svoja iskustva i poglede, odnosno rasprave problem uloge i postupanja regulatornog tijela te sadržaja ekonomske regulacije kada su u pitanju tarifni sustavi za proizvodnju, prijenos, distribuciju i opskrbu električnom energijom. Naravno, postoji bitna razlika između, s jedne strane proizvodnje i opskrbe električnom energijom kao primarno tržišnih djelatnosti, dakle djelatnosti izloženih konkurenciji, i s druge strane infrastrukturnih prirodnih monopolnih djelatnosti prijenosa i distribucije električne energije, koji su u pravilu regulirane djelatnosti. Zakonodavni i regulatorni okvir u kojem postoji jasno izražena obveza javne usluge opskrbe tarifnih kupaca taj kontekst može djelomično izmijeniti na način da energetske djelatnosti proizvodnje i opskrbe električnom energijom i nadalje ostaju predmetom ekonomske regulacije i nadzora energetskog regulatornog tijela. Tako su u ovom slučaju sve četiri navedene usluge stavljene u kontekst općeg ekonomskog (gospodarskog) interesa i povjerena jednom poduzeću, da bi se osigurala sigurna, redovita i kvalitetna opskrba energijom po razumnim cijenama, vodeći računa o zaštiti okoliša. U svakom slučaju, problematika odabira pristupa i utvrđivanja metodologije ekonomske regulacije i donošenja odgovarajućih tarifnih sustava za svaku od navedenih energetskih djelatnosti, koje su ranije bile uključene u integrirani tarifni sustav, i na koje se sada trebaju primijeniti zasebni tarifni sustavi, stvara jedan potpuno novi problem koji je uz to praćen problemom efikasnog odvajanja energetskih djelatnosti. Dakako, sustavi i regulatorna tijela drugih zemalja bili su suočeni i suočavaju se sa sličnim pitanjima i problemima. Stoga je bilo važno raspraviti neka pitanja i dileme iz predmetne problematike s predstavnicima raznih zainteresiranih strana, a poglavito je bilo važno čuti iskustva i stavove relevantnih eksperata iz europskih regulatornih tijela i zemalja s višegodišnjim iskustvom u ekonomskoj regulaciji, bilo da se radi o dugogodišnjim članicama EU, ili zemljama koje su tek nedavno postale članice EU.

# 1 INTRODUCTION

At the initiative of SC C5 – Electricity Markets and Regulation, the Croatian National Committee of CIGRÉ, the Round Table Discussion on the Role of the Regulatory Agency in the Adoption of Tariff Systems was held in Zagreb on May 15, 2007.

The Round Table Discussion was organized with the purpose and goal of providing the opportunity for representatives of the regulatory bodies and the regulated entities to present their experiences and views in the presence of the professional public, i.e. discuss the problem of the role and approach of the regulatory agency and the content of economic regulation regarding the question of the tariff systems for the generation, transmission, distribution and supply of electricity. Naturally, there are significant differences between the generation and supply of electricity as primary market activities, i.e. activities subject to competition on the one hand, and on the other hand the infrastructural natural monopolistic activities of the transmission and distribution of electricity, which as a rule are regulated activities. The legislative and regulatory framework in which there are clearly expressed public service obligation supplying tariff customers can partially alter this context in that the energy activities of the generation and supply of electricity continue to remain subject to economic regulation and supervision by the energy regulatory agency. All four of the stated services are considered to be of general economic interest and entrusted to a single enterprise in order to assure a reliable, regular and quality energy supply at reasonable prices, while taking environmental protection into account. In any case, the problems of selecting an approach, determining a methodology for economic regulation and adopting the suitable tariff systems for each of the cited energy activities that were previously included within an integrated tariff system, for which it is now necessary to apply separate tariff systems, create a completely new problem which is accompanied by the problem of the effective separation of energy activities. Certainly, the systems and regulatory agencies of other countries have been confronted with similar questions and problems. Therefore, it was important to discuss certain questions and dilemmas regarding this topic with representatives of various interested parties and it was especially important to hear about the experiences and positions of relevant experts from the European regulatory agencies and countries with many years of experience in economic regulation, whether longstanding members of the European Union or countries that have only recently become members of the EU.

U radu Okruglog stola po pozivu su uz prezentacije i predavanja, te kroz diskusije različitih uloga i nadležnosti regulatornih tijela, ali i praktičnih pristupa regulaciji i problemu donošenja tarifnih sustava, sudjelovali predstavnici regulatornih tijela Francuske, Austrije, Slovenije, Mađarske i Hrvatske, te predstavnici Hrvatske elektroprivrede d.d., odnosno predstavnici energetskih subjekta u Republici Hrvatskoj za koje se donose i primjenjuju odgovarajući tarifni sustavi. Okrugli stol pobudio je veliki interes stručne javnosti i intenzivnu diskusiju problema i sadržaja uloge regulatornog tijela kada su u pitanju regulatorni pristupi i metode ekonomske regulacije energetskih djelatnosti, dakako onih energetskih djelatnosti koji imaju monopolne pozicije ili kojima su pridijeljene obveze javnih usluga. Interes za teme metodologija tarifnih sustava, strukture, utjecajnih parametara, podloga i dokaza za utvrđivanje razine tarifnih stavki i inače pobuđuju veliki interes, što se očitovalo i na ovom Okruglom stolu.

## 2 OSNOVNI ZAKONODAVNI OKVIR EU ZA USPOSTAVU TRŽIŠTA ELEKTRIČNE ENERGIJE I SADRŽAJ REGULACIJE

Ključni akti Europske komisije koji definiraju opći okvir osnivanja i rada energetskih regulatornih tijela, odnosno utvrđuju opće smjernice i standarde organizacije energetskog tržišta i nadležnosti tih tijela u svezi električne energije su:

- Direktiva 2003/54/EZ Europskog parlamenta i Vijeća ministara o općim pravilima za unutrašnje tržište električne energije i prestanku važenja Direktive 96/02/EZ, koja utvrđuje opća pravila za proizvodnju, prijenos, distribuciju i opskrbu električnom energijom, te definira pravila o organizaciji i funkcioniranju elektroenergetskog sektora, pristupa tržištu, kriterije i postupke koji se primjenjuju za objavu nadmetanja i davanje odobrenja i upravljanje sustavima,
- Direktiva 2003/55/EZ Europskog parlamenta i Vijeća o zajedničkim pravilima unutarnjeg tržišta prirodnog plina i ukidanju Direktive 98/30/EZ, koja utvrđuje zajednička pravila za prijenos, distribuciju, opskrbu i skladištenje prirodnog plina, LNG-a i druge tipove plinova koji se mogu tehnički i sigurno ubacivati i transportirati kroz sustav za prirodni plin, te definira pravila o organizaciji i funkcioniranju sektora, pristupa tržištu, kriterije i postupke

In the Round Table Discussion, in addition to invited presentations, lectures and the discussion of the various roles and authorities of regulatory agencies, as well as practical approaches to regulation and the adoption of tariff systems, representatives of the regulatory agencies of France, Austria, Slovenia, Hungary and Croatia as well as representatives of Hrvatska elektroprivreda d.d., i.e. representatives of the energy entities in the Republic of Croatia who adopt and apply the corresponding tariff systems, also participated. The Round Table Discussion aroused great interest among the professional public and provoked intense discussion on the problem and content of the role of the regulatory agency regarding regulatory approaches and methods for the economic regulation of energy activities, i.e. those energy activities that have a monopoly position or to whom the public service obligation has been assigned. The topics of the methodologies of the tariff systems, the structure, influential parameters, basis and evidence for the determination of various tariff items attract great interest generally, which was also apparent at this Round Table Discussion.

## 2 THE BASIC LEGISLATIVE FRAMEWORK OF THE EUROPEAN UNION FOR THE ESTABLISHMENT OF AN ELECTRICITY MARKET AND THE CONTENT OF REGULATION

The key acts of the European Commission that define the general framework for the establishment and activity of energy regulatory agencies, i.e. determine the general guidelines and standards for the organization of the energy market and the authorities of these bodies in connection with electricity, are as follows:

- Directive 2003/54/EC of the European Parliament and of the Council of Ministers on Common Rules for the Internal Market in Electricity and Repealing Directive 96/02/EC, that determines the general rules for the generation, transmission, distribution and supply of electricity and defines the rules on the organization and function of the electricity sector, market approach, the criteria and processes that are applied for announcing tendering procedures, issuing authorizations and managing systems,
- Directive 2003/55/EC of the European Parliament and of the Council Concerning Common Rules for the Internal Market in Natural Gas and Repealing Directive 98/30/EC, which determines the common rules for the transmission, distribution, supply and storage of natural gas, liquefied

koji se primjenjuju na davanje odobrenja i rad sustava,

– Uredba 1228/2003/EZ Europskog parlamenta i Vijeća o uvjetima pristupa mreži za prekograničnu razmjenu električne energije, te
– Uredba 1775/2005/EZ o uvjetima pristupa transportnim mrežama za prirodni plin.

Unutar tog općeg zakonodavnog okvira regulatornom tijelu mogu se dodijeliti različite nadležnosti i odgovornosti, odnosno poslovi. Na Okruglom stolu prezentacijama i raspravom primarno su bile obuhvaćene nadležnosti i uloga regulatornog tijela u pogledu donošenja metodologija tarifnih sustava i/ili određivanja tarifa/naknada za energetske usluge, odnosno krajnje kupce. Neposredno u svezi s tim prezentirani su i raspravljeni i mogući pristupi reguliranju monopola ili javnih usluga (cijena korištenja mreže, uvjeta pristupa mrežama, pravila za vođenje sustava, uvjeta osiguranja stabilnosti i pouzdanosti sustava, pravila i uvjeta osiguranja pomoćnih usluga sustava). Širom raspravom bile su obuhvaćene i ostale nadležnosti i poslovi koji se u pravilu dodjeljuju regulatornom tijelu, kao što su nadzor standarda kvalitete i izvedbe, kreiranje i provođenje općih uvjeta, propisa i standarda, reguliranje ulaska energetskih subjekata u sektor (dozvole, povlašteni statusi, priključenja, nova izgradnja) i nadzor nad tržištem, izvještavanje, savjetovanje vlade, ministarstava, javnosti, rješavanje žalbi na rad operatora sustava i rješavanje žalbi i sporova kupaca.

Na Okruglom stolu jasno je pokazano da je unutar tog jednog općeg zakonodavnog okvira svaka zemlja članica EU razvila i uspostavila vlastiti zakonodavni i regulatorni okvir za tržište električne energije i rad nacionalnog regulatornog tijela, temeljeći rješenja i praksu na važećem osnovnom nacionalnom pravnom i zakonodavnom sustavu. Opće je pravilo, a isto je više puta i u svim slučajevima ponovljeno na gotovo istovjetan način od strane predstavnika regulatornih tijela Francuske, Austrije, Slovenije, Mađarske i Hrvatske, sudionika Okruglog stola, da je cilj svake zemlje uspostaviti neovisno i efikasno nacionalno regulatorno tijelo koje će stvoriti uvjete i nadzirati razvoj i uspostavu razvidnog, efikasnog i nepristranog tržišta električne energije i plina na dobrobit svih sudionika tih tržišta i krajnjih korisnika. Preduvjeti razvidnog, efikasnog i nepristranog tržišta električne energije i plina su osiguranje i provedba razvidnog i nediskriminirajućeg pristupa energetskim mrežama po unaprijed poznatim, reguliranim uvjetima, neovisan i nepristran rad operatora energetskih sustava, razvidno i nepristrano rješavanje sporova i prigovora na pristupe mrežama i rad operatora mrežnih sustava, efikasna provedba i garancije računovodstvenog i upravljačkog

natural gas (LNG) and other types of gases that can technically and safely be injected into and transported through the natural gas system, and defines the rules on the organization and function of the sector, market access, criteria and procedures that are applicable to the granting of authorizations and the operation of the system,

– Regulation 1228/2003/EC of the European Parliament and of the Council on Conditions for Access to the Network for Cross-Border Exchanges in Electricity, and
– Regulation 1775/2005/EC of the European Parliament and of the Council on Conditions for Access to the Natural Gas Transmission Networks.

Within this general legislative framework, various authorizations and responsibilities, i.e. tasks can be assigned to a regulatory agency. At the Round Table, the presentations and discussions were primarily about the authorities and roles of the regulatory agency regarding the adoption of methodologies for tariff systems and/or determining tariffs/charges for energy services, i.e. the final customers. In connection with this, potential approaches to the regulation of monopolies or public services were presented and discussed (the cost of network use, conditions for network access, rules for system management, conditions for assuring the stability and reliability of a system, and rules and conditions for securing auxiliary system services). Broader discussions included other authorities and tasks that as a rule are assigned to the regulatory body, such as the supervision of the standards for quality and implementation, the creation and implementation of general conditions, regulations and standards; regulation of the entry of energy entities into the sector (permits, privileged status, connections and new construction) and supervision over the market, reporting; advising the government, ministries and public; the settling of complaints regarding the work of the system operator, and customer complaints and disputes.

At the Round Table Discussion, it was clearly demonstrated that within this general legislative framework, each Member Country of the EU has developed and established its own legislative and regulatory framework for the electricity market and the work of the national regulatory agency, based upon the solutions and practice of the prevailing basic national legal and legislative system. As a general rule, which was repeated in all cases in a nearly identical manner in the presentations by the representatives of the regulatory agencies of France, Austria, Slovenia, Hungary and Croatia, i.e. the Round Table participants, the goal of every country is to establish an independent and efficient national regulatory agency that will create the conditions, supervise the development and establish transparent, efficient and nondiscriminatory electricity and gas markets for the benefit of all the

razdvajanja energetskih djelatnosti, sprječavanje međusobnih subvencioniranja reguliranih i nereguliranih djelatnosti unutar vertikalno ili horizontalno integriranih sustava, efikasan sustav prekograničnih razmjena, razvoj i uspostava efikasnih tržišnih mehanizama i slobodna tržišna utakmica itd.

S druge strane, činjenice i pojavnost su da regulatorna tijela u različitim zemljama imaju različite pozicije u odnosu na državna tijela i institucije, prvenstveno odgovarajuće vlade i ministarstva, te različite uloge i nadležnosti. U nekim zemljama regulatorna tijela su organizacijska jedinica ili dio ministarstva ili pod nadzorom ministarstva ili vlade. U drugim zemljama su ili značajno ili u potpunosti neovisna tijela. U nekim zemljama regulatorna tijela imaju nadležnost i obvezu nadzora provedbe podzakonskih akata, donošenja metodologija tarifnih sustava, davanja odobrenja na planove razvoja i planove investiranja reguliranih subjekata, nadzora provedbe ili primjene tarifnih sustava i tarifa, nadzora financijskog poslovanja, nadzora provedbe računovodstvenog i upravljačkog razdvajanja, nadzora kvalitete energetskih usluga, davanja odgovarajućih mišljenja i savjetovanja ministarstava i vlada o cijenama, tarifama, pitanjima uspostave energetskog tržišta i sl. U drugim zemljama nacionalna regulatorna tijela imaju jaču ulogu i nadležnosti, koje uključuju donošenje odgovarajućih podzakonskih akata, ali i poduzimanje odgovarajućih mjera, utvrđivanje tarifa i uvjeta pristupa mrežama, rješavanje sporova u svezi s pristupom mrežama i uvjetima korištenja mreža, rješavanje prigovora i žalbi na rad operatora mrežnih sustava, rješavanje prigovora i žalbi krajnjih kupaca i slično. Nisu zanemarivi i sustavi mjera i sankcija koje nekim regulatornim tijelima stoje na raspolaganju da bi osnažili svoje djelovanje i odluke.

Kada su u pitanju nadležnosti za definiranje i donošenje metodologija ekonomske regulacije, odnosno izbor, definiranje i donošenje osnovnog regulacijskog pristupa, metodologije tarifnog sustava i samih tarifa, uloge regulatornih tijela se razlikuju. Opet, u nekim zemljama regulatorna tijela imaju ključnu ulogu u svim segmentima procesa od definiranja metode regulacije i metodologije tarifnog sustava, nadzora poslovanja i revizije financijskih pokazatelja i izvješća energetskih subjekata, dubinske revizije i odobravanja troškova, definiranja i odobravanja ključnih regulacijskih i makroekonomskih parametara, primjene mehanizama javnog prezentiranja i očitovanja javnosti, odnosno korisnika i kupaca o iznosima tarifnih stavki itd. U drugim zemljama regulatornim tijelima dane su u nadležnost i obveze samo neka od navedenih prava, poslova i obveza. Najčešći

participants of these markets and the final customers. The prerequisites for transparent, efficient and nondiscriminatory electricity and gas markets are the assurance and implementation of transparent and nondiscriminatory access to the energy networks according to previously specified regulatory conditions, the independent and nondiscriminatory work of the energy system operators, the transparent and nondiscriminatory resolution of disputes and complaints regarding network access and the work of the network system operators, the efficient implementation and guarantee of the accounting and managerial unbundling of energy activities, the prevention of cross subsidies among regulated and unregulated activities within vertically or horizontally integrated systems, an effective system for cross-border exchanges, the development and establishment of efficient market mechanisms and free market competition etc.

Otherwise, the regulatory agencies in various countries have differing positions in relation to the state agencies and institutions, primarily the corresponding governments and ministries, and various roles and authorities. In some countries, the regulatory agencies are organizational units, parts of a ministry or under the supervision of a ministry or the government. In other countries, they are either considerably or entirely independent bodies. In some countries, the regulatory bodies have the authority and responsibility of supervising the implementation of bylaws, the adoption of the methodologies of the tariff systems, granting approval for the development and investment plans of the regulated entities, supervision over the implementation or application of tariff systems and tariffs, supervision over financial operations, supervision over the implementation of accounting and managerial unbundling, supervision over the quality of energy services, issuing suitable opinions and advising ministries and the government regarding prices, tariffs, questions regarding the establishment of the energy market etc. In other countries, the national regulatory agency has a strong role and powerful authority, including the adoption of suitable bylaws but also the undertaking of suitable measures for the determination of tariffs and conditions for network access, the settlement of disputes in connection with network access and conditions for network use, the settlement of complaints regarding the work of the network system operator, the settlement of complaints from the final customers etc. The system of measures and penalties that some regulatory agencies have at their disposal to enforce their activity and decisions is not insignificant.

When authorities are in question for the definition and adoption of methodologies for economic regulation, i.e. the selection, definition and adoption of the basic regulatory approach, methodologies of the tariff system and tariffs themselves, the roles of the

je slučaj da regulatorno tijelo ima obvezu i odgovornost za donošenje odgovarajuće metodologije tarifnih sustava, te nadzora poslovanja i troškova reguliranih subjekata. Regulatorna tijela u nekim zemljama daju mišljenja odgovarajućim ministarstvima i vladama u pogledu visine tarifnih stavki, u drugim zemljama imaju nadležnost utvrđivanja, odnosno reguliranja tarifnih stavki, što je u pravilu i cilj njihova osnivanja.

Konačno, nužno je ukazati i na treći aspekt ili razinu mogućih nadležnosti i odgovornosti regulatornih tijela. Tu treću razinu čine pristupi pojedinim segmentima ili problemima ekonomske regulacije kao što su problemi kriterija za pridjeljivanje i priznavanje razine operativnih troškova poslovanja, odobravanja i priznavanja investicija u nove objekte, postrojenja i instalacije, troškova kapitala, odnosno amortizacije i povrata na uložena sredstva, utvrđivanja odgovarajuće regulatorne baze i stope povrata na reguliranu imovinu, priznavanja odgovarajućih inflatornih utjecaja na troškove i tarife, utvrđivanja i priznavanja i drugih korektivnih faktora na troškove i tarife, te konačno i postupanja u slučaju viškova i manjkova prihoda na karaju regulacijskog perioda. Posebno je pitanje odnosa i postupanja prema kategorijama prihoda koji imaju obilježja profita. Naravno, za ovaj treći regulacijski aspekt vezana su i pitanja, odnosno problemi koliko dug regulacijski period ustanoviti, kada primijeniti jednostavne, a kada početi primjenjivati složene metode ekonomske regulacije.

Često je prisutna i dilema kada uvesti poticajnu regulaciju, kako složene regulacijske pristupe i mehanizme učiniti razumljivim, razvidnim i prihvatljivim svim sudionicima, naročito energetskim subjektima koji iste trebaju primijeniti i korisnike ili kupce na koje se isti odnose, i končano, kako osigurati da ti mehanizmi u sukcesivnom slijedu rezultiraju stabilnom i efikasnom strukturom tarifa i sl. Za mrežne infrastrukturne sustave i prirodne monopolne energetske djelatnosti uz navedene treba dodati i pitanja odgovornosti i načina osiguravanja pomoćnih usluga sustava, pokriće troškova gubitaka, odgovornosti za pravovremen i dostatan razvoj i izgradnju sustava, te izgradnju dostatnih prekograničnih kapaciteta. Dodatno, operatori prijenosnog i distributivnog sustava imaju i odgovornosti u pogledu uključivanja i osiguravanja uvjeta za rad postrojenja koja koriste obnovljive izvore energije.

regulatory agencies differ. In some countries, the regulatory bodies have a crucial role in all the segments of the process, including the definition of the method for regulation and the methodology of the tariff system, supervision over operations and the auditing of financial indices and reports of energy entities, in-depth auditing and approval of expenditures, the definition and approval of crucial regulatory and macroeconomic parameters, the application of mechanisms for presentations and statements to the public, i.e. users and customers, about the amounts of tariff items etc. In other countries, the regulatory agencies are granted the authority and responsibility for only some of the stated rights, activities and responsibilities. The most frequent case is that a regulatory agency has the obligation and responsibility for the adoption of a suitable tariff system methodology, together with the supervision of the operations and expenditures of the regulated entities. The regulatory bodies in some countries issue an opinion to the corresponding ministries and governments regarding the amounts of tariff items, and in other countries they have the authority to determine or regulate the tariff items, which as a rule is the purpose for their establishment.

Finally, it is necessary to draw attention to the third aspect or level of the potential authorities and responsibilities of regulatory bodies. This third level consists of approaches to individual segments or problems of economic regulation, such as the problems of the criteria for the allocation and recognition of the level of operational costs, approval and recognition of investments in new facilities, plants and installations; capital costs, i.e. depreciation and investment return, determination of the suitable regulatory basis and rate of return on regulated property, recognition of the impact of inflation on costs and tariffs; the determination and recognition of other corrective factors on costs and tariffs, and finally the procedure in the event of revenue surpluses and deficits at the end of the regulatory period. A particular question refers to the attitude and procedure toward the categories of revenue that have recorded profits. Naturally, questions are connected with this third regulatory aspect, i.e. problems regarding how long a regulatory period should be established, when simple methods should be applied and when it is necessary to begin to apply complex methods of economic regulation.

There is often the issue of when to introduce incentive regulation, how to make complex regulatory approaches and mechanisms understandable, transparent and acceptable to all the participants, especially energy entities who must apply them and the users or customers to which they refer, how to assure that these mechanisms successively result in a stable and efficient tariff structure etc. For network infrastructure systems and naturally monopolistic

## 3 RESTRUKTURIRANJE ELEKTROENERGETSKOG SEKTORA, REGULACIJA I TARIFNI SUSTAVI U REPUBLICI HRVATSKOJ

U uvodnom dijelu Okruglog stola detaljno je izložen kontekst energetskog zakonodavnog okvira i procesa restrukturiranja elektroenergetskog sektora, odnosno otvaranja tržišta električne energije i razvoja i uspostavljanja novog regulatornog okvira u Republici Hrvatskoj [1], [2] i [3]. U tom kontekstu i okružju donesene su i objavljene metodologije tarifnih sustava, a tek treba utvrditi odgovarajuće stavke za prijenos i distribuciju električne energije te proizvodnju i opskrbu električnom energijom s izuzetkom za povlaštene kupce.

Naime, temeljem vrijedećih zakona Hrvatska energetska regulatorna agencija (u daljnjem tekstu: Agencija) ima obvezu i odgovornost, nakon pribavljenog mišljenja energetskih subjekata za obavljanje čijih djelatnosti se primjenjuje tarifni sustav i Ministarstva gospodarstva, rada i poduzetništva (u daljnjem tekstu: Ministarstvo), u sektoru električne energije donijeti metodologije tarifnih sustava, odnosno tarifne sustave bez visine tarifnih stavki, i to za: 1) proizvodnju električne energije, s iznimkom za povlaštene kupce, 2) opskrbu električnom energijom, s iznimkom povlaštenih kupaca, 3) prijenos električne energije, 4) distribuciju električne energije, 5) utvrđivanje naknade za priključak na prijenosnu i distribucijsku mrežu, te povećanje priključne snage, 6) pružanje usluga uravnoteženja električne energije u elektroenergetskom sustavu.

Prethodno navedene metodologije moraju omogućavati ulaganja potrebna za razvoj mreže i ostale zahtjeve sukladno postojećim zakonima.

Temeljem vrijedećih zakona energetski subjekt za obavljanje čijih djelatnosti se primjenjuje tarifni sustav podnosi prijedlog visine tarifnih stavki Ministarstvu, koje nakon pribavljenog mišljenja Agencije predlaže iznose tarifnih stavki Vladi Republike Hrvatske. Vlada Republike Hrvatske utvrđuje visinu tarifnih stavki. Agencija provodi nadzor primjene tarifnih stavki i svih ostalih naknada.

Na Okruglom stolu detaljno je izložen kontekst utvrđivanja i sadržaja metodologija tarifnih sustava za proizvodnju električne energije, s iznimkom za povlaštene kupce, opskrbu električnom energijom, s iznimkom povlaštenih kupaca, prijenos električne energije i distribuciju električne energije. U nastavku slijedi prikaz do sada vrijedećeg

energy activities, is also necessary to add questions of responsibility and the manner of assuring auxiliary services for the system, covering losses, responsibility for the timely and suitable development and construction of the system, and the construction of adequate cross-border capacities. Additionally, the transmission and distribution system operators have responsibilities in respect to the inclusion and assurance of the conditions for the operation of the plants that use renewable energy sources.

## 3 RESTRUCTURING OF THE ELECTRICITY SECTOR, REGULATION AND TARIFF SYSTEMS IN THE REPUBLIC OF CROATIA

In the introductory part of the Round Table Discussion, the context of the legislative framework for energy and the process of the restructuring of the electricity sector, i.e. opening the electricity markets and the development and establishment of a new regulatory framework in the Republic of Croatia, were presented in detail [1], [2] and [3]. In this context and environment, methodologies for tariff systems were adopted and published, and it is necessary to determine the corresponding tariffs for the transmission and distribution of electricity and production and supply of electricity with exceptions for eligible customers.

Based upon the prevailing legislation, the Croatian Energy Regulatory Agency (henceforth: the Agency) has the obligation and responsibility, after obtaining the opinions of the energy to entities to whose activities the tariff system is applied, and the Ministry of the Economy, Labor and Entrepreneurship (henceforth: the Ministry), to adopt methodologies for the tariff systems in the sector of electricity, i.e. the tariff systems without the amounts of the tariff items, and this for 1) the generation of electricity, with the exception of eligible customers, 2) the supply of electricity, with the exception of eligible customers, 3) the transmission of electricity, 4) the distribution of electricity, 5) the determination of connection fee to the transmission and distribution networks, and increasing the installed capacity, and vi) providing the services of balancing electricity within the electricity system.

The previously cited methodologies must facilitate the investment necessary for the development of the network and other requirements, pursuant to the existing legislation.

Based upon the prevailing legislation, the energy entities to whose activities the tariff system is ap-

integralnog tarifnog sustava koji je bio na snazi više godina, razloga za njegovu promjenu, te općih značajki pristupa i kontekst regulatornih mehanizama tarifnih sustava u Republici Hrvatskoj koji su doneseni i stupili na snagu u prosincu 2006. godine [4], [5], [6] i [7]. Naravno, kroz sve te sadržaje odražava se i specifična pozicija i uloga hrvatskog energetskog regulatornog tijela – Agencije. Međutim, ogleda se i težina problema konteksta, odnosno opsega i sadržaja regulacije energetskih djelatnosti u sektoru električne energije.

Naime, nije naodmet ponoviti i činjenicu da se potreba za organizacijom Okruglog stola pojavila u momentu kada su u Republici Hrvatskoj donesena i stupila na snagu četiri nova tarifna sustava, bez visine tarifnih stavki, tj. metodologije za izračun zasebnih tarifnih stavki za djelatnosti proizvodnje, prijenosa, distribucije i opskrbe električnom energijom. Iste su do sada bile komponente jedinstvene tarife za integrirani sustav djelatnosti proizvodnje, prijenosa, distribucije i opskrbe električnom energijom, odnosno svih usluga povezanih s opskrbom električnom energijom krajnjih kupaca. Sukladno jasnoj zakonskoj obvezi razdvajanja navedenih djelatnosti, izraženih i kroz pristup spomenutim metodologijama tarifnih sustava, u tijeku su poslovi vezani uz izračun i donošenje tarifnih stavki za navedene temeljne energetske djelatnosti. Primjenom spomenutih metodologija, odnosno donošenjem i stupanjem na snagu novih tarifnih stavki elektroenergetski sektor i elektroenergetsko gospodarstvo Republike Hrvatske ući će u prvo regulatorno razdoblje.

Stoga je i za regulatorno tijelo, za predstavnike reguliranih djelatnosti, jednako tako i za stručnu javnost od velike važnosti i pomoći bilo raspraviti neka pitanja i dileme iz predmetne problematike, i to upravo na skupu s predstavnicima raznih zainteresiranih strana. Poglavito je bilo važno čuti iskustva i stavove relevantnih eksperata iz europskih regulatornih tijela i zemalja s višegodišnjim iskustvom u ekonomskoj regulaciji, bilo da se radi o dugogodišnjim članicama EU, ili zemljama koje su tek nedavno postale članice EU. U uvodnom dijelu predstavnici Agencije i reguliranih subjekata u Republici Hrvatskoj detaljno su predstavili ulogu Agencije kao regulatornog tijela, odabrane i primijenjene regulacijske pristupe i mehanizme, odnosno sadržaje i elemente metodologije tarifnih sustava koji su u Republici Hrvatskoj doneseni u prosincu 2006. godine za energetske djelatnosti prijenosa i distribucije električne energije te proizvodnje i opskrbe električnom energijom s iznimkom za povlaštene kupce [8], [9] i [10]. Okrugli stol pružio je izvrsnu prigodu za usporedbu i diskusiju hrvatskog zakonodavnog i regulatornog okružja, odnosno regulacijskog pristupa i meha-

plied submit a proposal for the amounts of the tariff items to the Ministry, which after obtaining the opinion of the Agency proposes the amounts of the tariff items to the Government of the Republic of Croatia. The Government of the Republic of Croatia determines the amounts of the tariff items. The Agency supervises the application of the tariff items and all other compensation.

At the Round Table Discussion, the context for the determination and content of the methodology of the tariff systems for the generation of electricity was presented in detail, with an exception for favored customers, as well as the supply of electricity, with an exception for favored customers, the transmission of electricity and the distribution of electricity. A presentation follows of the valid integrated tariff system that was in force for many years, the reasons for changing it, and the general characteristics of the approach and context of the regulatory mechanisms of the tariff system in the Republic of Croatia that were adopted in December 2006 and have gone into effect [4], [5], [6] and [7]. Naturally, the specific position and role of the Croatian Energy Regulatory Agency is reflected in all of this. However, the difficulty with the context of the problem, i.e. the range and content of the regulations of the energy activities in the electricity sector, are also reflected.

It is necessary to reiterate the fact that the need for the organization of the Round Table Discussion came at the moment when the Republic of Croatia had adopted and placed into force four new tariff systems, without specifying the amounts of the tariff items, i.e. the methodology for the calculation of the separate tariff items for the activities of the generation, transmission, distribution and supply of electricity. Until now, they were components of a single tariff for the integrated system of the activities of the generation, transmission, distribution and supply of electricity, i.e. all the services connected with the supply of electricity to final customers. Pursuant to the clear legal obligation for the separation of these activities, also expressed through the approach of the previously mentioned methodologies of the tariff system, work is in progress in connection with the calculation and adoption of the tariff items for these basic energy activities. Through the application of the previously mentioned methodologies, i.e. the adoption and going into force of the new tariff items of the electricity sector and the economy of the Republic of Croatia, a trial regulatory period will be entered.

Therefore, for the regulatory agency, the representatives of the regulated entities, and the professional public, it would be of great importance and benefit to discuss several questions and dilemmas regard-

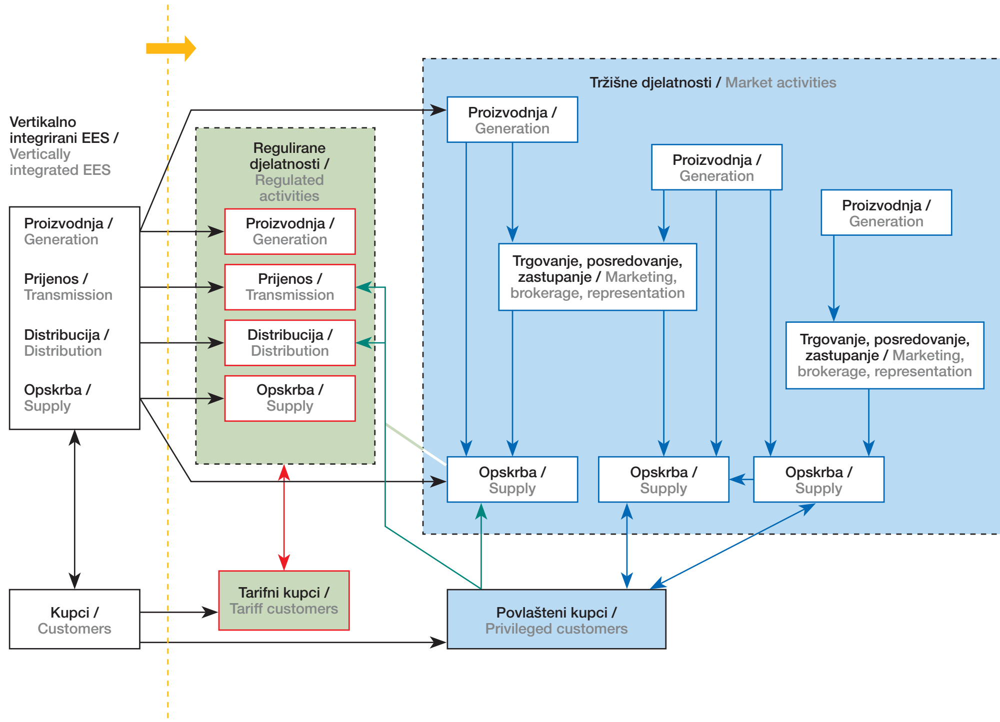
nizma, uključujući i sadržaje i elemente metodologije tarifnih sustava, s odgovarajućim okružjima, ulogama regulatornih tijela, odnosno pristupima, sadržajima i elementima regulacije i tarifnih sustava u Francuskoj, Austriji, Sloveniji i Mađarskoj i Hrvatske [11], [12], [13] i [14].

Na slici 1 prikazan je tijek procesa restrukturiranja elektroenergetskog sektora i tržišta električne energije, iz njegove vertikalno integrirane strukture u strukturu koja u svezi s tržišnim djelatnostima proizvodnje električne energije i opskrbe električnom energijom primarno podrazumijeva konkurentno okružje i tržišnu utakmicu, a glede monopolnih mrežnih infrastrukturnih sustava regulirano okružje po principu reguliranog pristupa treće strane, dakle po tarifama i ostalim uvjetima pristupa koji su unaprijed utvrđeni, razvidni i nepristrani. Specifična struktura regulacije i tarifnih sustava uvjetovana je zakonom utvrđenom obvezom javne usluge opskrbe električnom energijom tarifnih kupaca. Očito je da će tu specifičnu strukturu u budućnosti značajno uvjetovati dinamika otvaranja tržišta električne energije, tj. brzina kojom će se segment opskrbe i obveza prema tarifnim kupcima smanjivati, a segment povlaštenih kupaca rasti.

ing these problems at a meeting with the representatives of various interested parties. It would be especially important to hear about the experiences and positions of the relevant experts from the European regulatory bodies and countries with many years of experience in economic regulation, whether these countries that have been members of the EU for many years or have only recently become members of the EU. In the introductory section, representatives of the Agency and the regulated entities in the Republic of Croatia presented the role of the Agency in detail as a regulatory body, the chosen and applied regulatory approaches and mechanisms, i.e. the contents and elements of the methodologies of the tariff systems that were adopted in the Republic of Croatia in December 2006 for the energy activities of the generation of electricity, with an exception for favored customers, the supply of electricity, with the exception of favored customers, the transmission of electricity and the distribution of electricity [8], [9] and [10]. The Round Table Discussion provided an excellent opportunity for the comparison and discussion of Croatian legislation and the regulatory environment, i.e. the regulatory approach and mechanisms, including the contents and elements of the methodology of the tariff systems, with the corresponding environments, roles of the regulatory bodies, i.e. the approaches, contents and elements of the regulations and tariff systems in France, Austria, Slovenia, Hungary and Croatia [11], [12], [13] and [14].

In Figure 1, the process of the reconstruction of the electricity sector and the electricity market is presented, from its vertically integrated structure in a structure that in connection with the market activities of the generation of electricity and the supply of electricity is primarily understood to mean the competitive environment and market competition, and regarding the monopolistic network infrastructure systems, the regulated environment according to the principle of the third party acces according to tariffs and other conditions of access that have been determined in advance, and are transparent and nondiscriminatory. The specific structure of the regulatory and tariff systems was conditioned by the legally established public service obligation of the supply of electricity to tariff customers. It is evident that this specific structure will significantly affect the dynamics of the opening of the electricity market in the future, i.e. the speed at which the supply segment and the obligation toward tariff customers will be reduced and the segment of privileged customers will grow.

**Slika 1**
Restrukturiranje elektroenergetskog sektora i tarifni sustavi u Hrvatskoj
**Figure 1**
Restructuring of the electrical energy sector and the tariff systems in Croatia

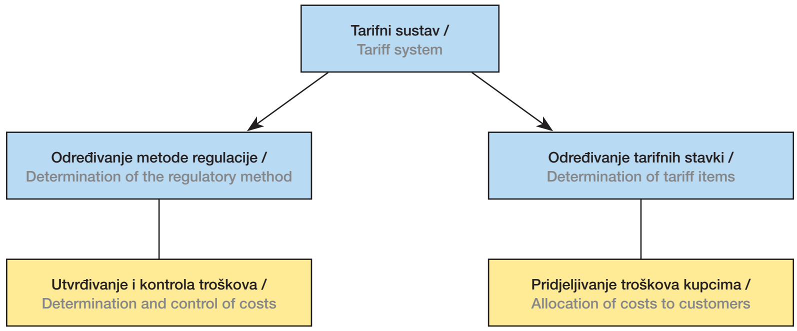



S druge strane izložena struktura ukazuje na to da je realno očekivati brze promjene konteksta, ali i sadržaja regulacije. Nije beznačajno ukazati i na dvojnost, bolje rečeno složenost regulatornog sadržaja koji s jedne strane proizlazi iz potrebe da se definiraju sadržaji i razrađuju specifični elementi ekonomske regulacije za segment tzv. prirodnih monopolnih djelatnosti prijenosa i distribucije električne energije, koje su u pravilu svugdje ujedno i regulirane djelatnosti, a s druge strane iz potrebe da se, premda ipak privremeno i do potpunog otvaranja tržišta električne energije, razviju i uvedu regulacijski mehanizmi za tržišne djelatnosti proizvodnje i opskrbe električnom energijom. Tržišne djelatnosti općenito i općeprihvaćeno trebaju biti izložene konkurenciji. To samo svjedoči o težini zadatka i izazova s kojima se suočava regulatorno tijelo, ali i regulirani subjekti, kada je proizvodnju i opskrbu potrebno prevesti iz stanja monopola u stanje konkurencije.

Na slici 2 prikazana je osnovna struktura, odnosno sadržaji novih tarifnih sustava kako ih definira novi zakonodavni okvir u Republici Hrvatskoj.

On the other hand, the presented structure indicates that it is realistic to anticipate rapid changes in the context as well as the contents of regulation. It is necessary to mention the duality, better to say the complexity, of the regulatory content that from the one side issues from the need to define the contents and work out the specific elements of the economic regulation of this segment, the so-called naturally monopolistic activities of the transmission and distribution of electricity, which as a rule are also regulated activities everywhere; and from the other side the need for, albeit temporarily and until the complete opening of the electricity market, the development and introduction of the regulatory mechanisms for the market activities of the generation and supply of electricity. Market activities should generally be exposed to competition. This only testifies to the difficulty of the task and the challenges confronting the regulatory agency, but also the regulated entities, when generation and supply must be changed from a state of monopoly to a state of competition.

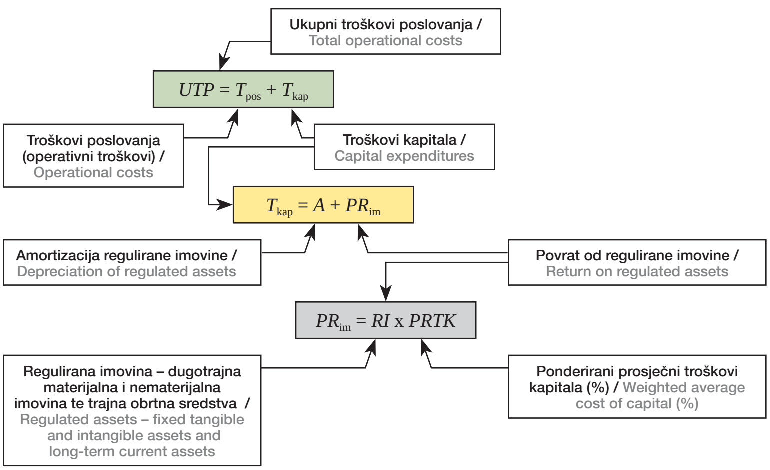
In Figure 2, the basic structure, i.e. content, of the new tariff systems is presented as defined by the new legislative framework in the Republic of Croatia.




**Slika 2**
Osnovna struktura i sadržaj novih tarifnih sustava
**Figure 2**
The basic structure and content of the new tariff systems

Ključni moment ili sadržaj regulacijskog procesa u kojem se definira pristup novom tarifnom sustavu je izbor osnovnog pristupa metodi regulacije (slika 3).

The crucial moment or content of the regulatory process in which the access to the new tariff system is defined is the selection of the basic approach to the method of regulation (Figure 3).




**Slika 3**
Izbor, sadržaj i mehanizam regulacije u novim tarifnim sustavima
**Figure 3**
The selection, content and mechanism of regulation in the new tariff systems

Ocjenjujući realnim i razumnim da se na početku prvog regulatornog razdoblja, dakle kada se po prvi put izlazi iz dugogodišnje integrirane tarifne strukture i jedinstvenih tarifnih stavki za sve energetske djelatnosti u sektoru električne energije i prelazi na odvojene pristupe i zasebne tarifne stavke za svaku od tih djelatnosti, odabere što jednostavniji, lakše primjenjiv i provedivi pristup i mehanizam, odabrana je opće poznata metoda priznatih troškova poslovanja, pri čemu se regulacija zapravo temelji i veže za kriterij stope povrata uloženog kapitala (eng. *Cost Plus* ili *Rate-of Return Regulation*). Dakle, slijedilo se odgovarajuće iskustvo i praksu više europskih zemalja i njihovih regulatornih tijela, koja su u početku procesa uvodila jednostavne regulacijske mehanizme, a

At the beginning of the first regulatory period, i.e. when for the first time the integrated tariff structure and single tariff items for all the energy activities in the power system will be replaced in transition to separate approaches and separate tariff items for each of these activities, it is realistic and reasonable to choose the simplest possible, easily applicable and feasible approach and mechanism. The generally known method of recognized costs of operations has been chosen, so that the regulation is actually based upon and connected with the criterion of the rate of return on investments. Furthermore, the corresponding experience and practice have been followed of several European countries and their regulatory agencies, which introduced simple regulatory mechanisms at the beginning of the process and then,

zatim s vremenom, kako su svi sudionici procesa stjecali odgovarajuća znanja i iskustva, uvodili sve složenije mehanizme, da bi danas primjenjivali složene mehanizme poticajne regulacije, ali i vrlo složene i zahtjevne procedure nadzora i kontrole svakog segmenta tih mehanizama. Tako npr. često su u regulacijske mehanizme uključeni neki od makroekonomskih gospodarskih parametara i pokazatelja, koji traže vrijeme za složenu i dugotrajnu analizu i elaboraciju. U pravilu se pokazuje da nije niti jednostavno niti opravdano bez ograde koristiti istovrsne pokazatelje primijenjene u drugim zemljama, pa čak niti prenositi i koristiti istovrsne pokazatelje primijenjene u drugim gospodarskim sektorima iste zemlje. Pogotovo je oprez nužan kada su u pitanju razina i struktura, odnosno način utvrđivanja odgovarajućih pokazatelja tržišnih rizika u svezi s ulaganjima, vlastitim kapitalom, dugovanjima i slično.

Zakon utvrđuje da se tarifni sustavi temelje na opravdanim troškovima poslovanja, održavanja, zamjene, izgradnje ili rekonstrukcije objekata i zaštite okoliša, uključujući razuman rok povrata sredstava od investicija u energetske objekte, uređaja i mreža, odnosno sustava, te moraju biti nepristrani i razvidni. Ujedno, tarifni sustavi trebaju poticati mehanizme za poboljšanje energetske učinkovitosti i upravljanje potrošnjom, uključujući i povećano korištenje obnovljivih izvora energije. Dakle, kod odabira temeljnog pristupa regulacije bilo je nužno voditi računa da prihod ostvaren primjenom novih tarifnih stavki treba pokriti sve apriznate ukupne troškove poslovanja, dakle priznate operativne troškove i troškove kapitala, od kojih troškove kapitala čine amortizacija regulirane imovine i povrat od regulirane imovine.

U hrvatskoj literaturi često se miješaju dva različita pojma:

- kapitalni troškovi *(CAPEX, Capital Expenditures),*
- trošak kapitala *(CC, Cost of Capital, odnosno WACC, Weighted Average CC).*

Reguliranom energetskom subjektu u općem slučaju treba omogućiti nadoknadu svih (priznatih) operativnih troškova, amortizacije, te troškova koje potražuju vlasnici financijskog kapitala, a to su:

- kamate i prinosi emitiranih korporacijskih obveznica,
- oportunitetni trošak vlasnika dioničarskog kapitala.

with time, when all the participants in the process had acquired the appropriate knowledge and experience, introduced progressively complex mechanisms in order to apply more complex mechanisms and incentive regulation today, but also highly complex and demanding procedures for the supervision and control of each segment of these mechanisms. Thus, for example, regulatory mechanisms frequently included some of the macroeconomic parameters and indices, which require time for complex and lengthy analysis and elaboration. As a rule, it has been shown that it is neither simple nor justifiable to use the same types of indices applied in other countries without limitation, or even to transfer and use the same types of indices applied in the other economic sectors of the same country. Caution is particularly necessary when the level and structure are in question, i.e. the manner of determining the corresponding indices of market risks in connection with investments, equity capital, debts etc.

The law establishes that the tariff systems are based upon the justified costs of the operations, maintenance, replacement, construction or reconstruction of facilities and environmental protection, including a reasonable period for the return of investments in energy facilities, equipment and networks, i.e. the systems, and must be nondiscriminatory and transparent. At the same time, tariff systems must promote mechanisms for the improvement of energy efficiency and the management of consumption, including the increased use of renewable energy sources. Therefore, in the selection of the basic approach to regulation, it was necessary to take into account that the income generated through the application of the new tariff items should cover all the known overall operational costs, i.e. the recognized operational costs and capital expenditures, which consist of the depreciation of the regulated property and the return from the regulated property.

In the Croatian literature, two different concepts are often confused:

- capital expenditures (*CAPEX*),
- cost of capital (*CC*, Cost of Capital, or *WACC*, Weighted Average *CC*).

Through the regulation of an energy entity in the general case, it is necessary to facilitate compensation for all (recognized) operative costs, depreciation and expenditures claimed by the owners of capital, as follows:

- interest and the income from corporate bonds issued,
- opportunity costs for stockholders.

Stopa povrata koja omogućuje naknadu troškova iz navedene dvije kategorije zove se ponderirani prosječni trošak kapitala *(WACC)*.

Po odabranom pristupu i metodi regulacije, određivanje visine tarifnih stavki za buduću regulacijsku godinu zasniva se na sljedećim troškovima:

a) priznatim ostvarenim troškovima poslovanja iz prethodne regulacijske godine,
b) ostvarenim i procijenjenim troškovima poslovanja za sadašnju regulacijsku godinu, te
c) prihvaćenim planskim vrijednostima troškova za razmatranu buduću regulacijsku godinu.

U reguliranu imovinu, temeljem koje se primjenom odgovarajuće priznate stope ponderiranog prosječnog troška kapitala računa povrat ili prinos od regulirane imovine, čine dugotrajna materijalna i nematerijalna imovina te trajna obrtna sredstva. Izložena osnovna struktura ili pristup primjenjuje se na sve djelatnosti: proizvodnju, prijenos, distribuciju i opskrbu električnom energijom.

Specifična temeljna struktura i osnovne stavke troškova poslovanja u svezi s proizvodnjom električne energije prikazana je na slici 4, u svezi s prijenosom električne energije na slici 5, s odgovarajućom posebnom razradom potrebnih podataka koja je prikazana na slici 6, u svezi s distribucijom električne energije na slici 7, te u svezi s opskrbom električnom energijom na slici 8.

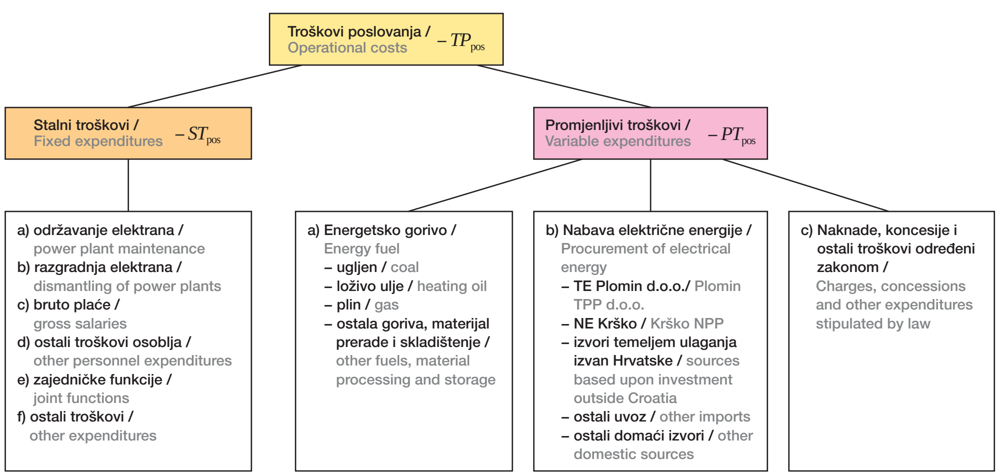
The rate of return that makes compensation for costs from the two cited categories possible is known as the weighted average cost of capital (WACC).

According to the selected approach and method of regulation, the determination of the level of the tariff items for the subsequent regulated year is based upon the following expenditures:

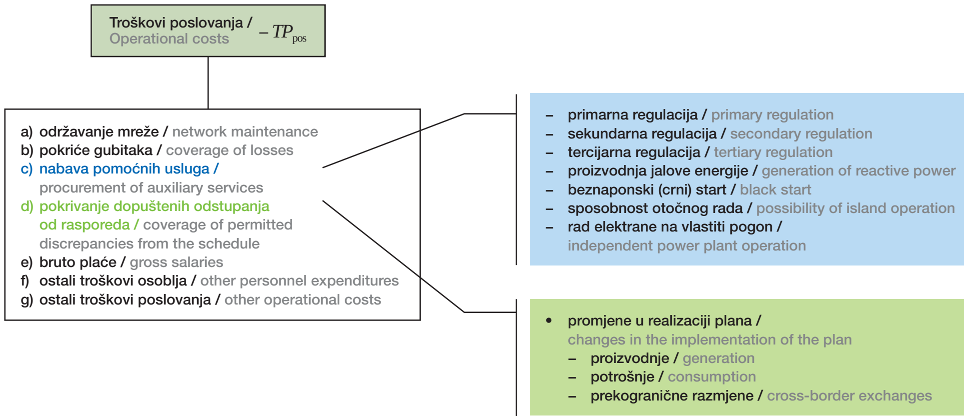
a) the recognized realized costs of operations during the previous regulated year,
b) the realized and estimated costs of operations for the current regulated year, and
c) the accepted planned values of expenditures for the analyzed subsequent regulated year.

For regulated property, according to which the corresponding recognized rate of the weighted average cost of capital is applied, the return or revenue is calculated and consists of fixed tangible assets, intangible assets and permanent current assets. The basic structure or approach presented is applied to all activities: the generation, transmission, distribution and supply of electricity.

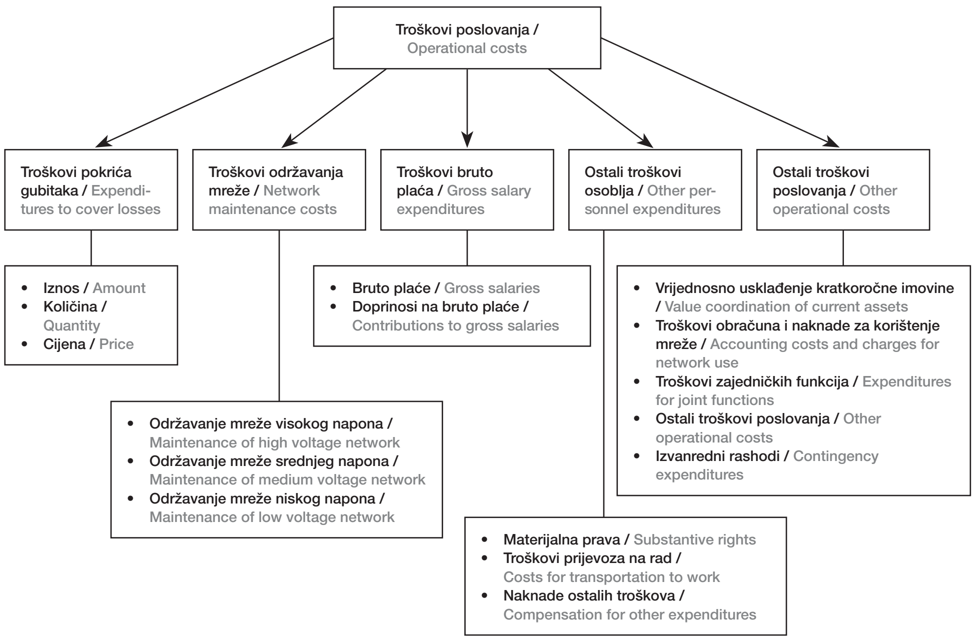
The specific fundamental structure and basic items of operational costs in connection with the generation of electricity are presented in Figure 4, in connection with the transmission of electricity in Figure 5, with the corresponding separate processing of the necessary data presented in Figure 6, the distribution of electricity in Figure 7 and in connection with the supply of electricity in Figure 8.



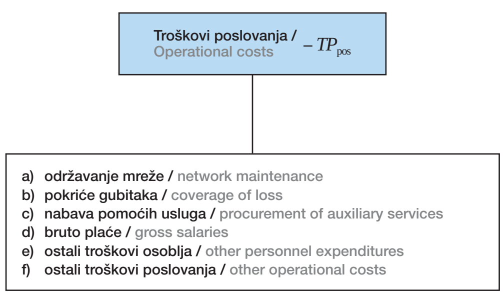

**Slika 4**
Tarifni sustav za proizvodnju električne energije (struktura troškova)
**Figure 4**
The tariff system for the production of electrical energy (the structure of expenditures)



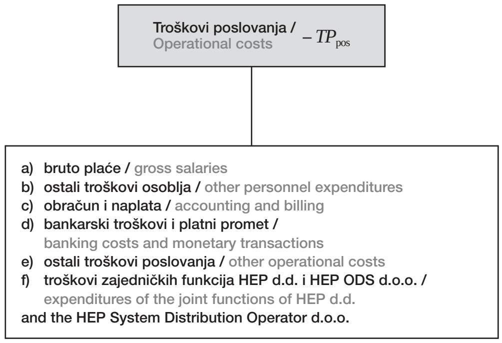

**Slika 5**
Tarifni sustav za prijenos električne energije (struktura troškova)
**Figure 5**
The tariff system for the transmission of electrical energy (the structure of expenditures)




**Slika 6**
Tarifni sustav za prijenos električne energije (struktura potrebnih podataka)
**Figure 6**
The tariff system for the transmission of electrical energy (the structure of the required data)




**Slika 7**
Tarifni sustav za distribuciju električne energije (struktura troškova)
**Figure 7**
The tariff system for the distribution of electrical energy (the structure of expenditures)




**Slika 8**
Tarifni sustav za opskrbu električnom energijom (struktura troškova)
**Figure 8**
The tariff system for the supply of electrical energy (the structure of expenditures)

Glede prijenosa električne energije, bolje rečeno HEP Operatora prijenosnog sustava problematiku pristupa regulaciji, odnosno tarifnom sustavu još složenijima čine i sljedeća pitanja, odnosno problemi novog okružja, kao što su:

- poslovanje HEP Operatora prijenosnog sustava na otvorenom tržištu,
- način utvrđivanja i tretmana troškova nastalih zbog prekograničnih tranzita električne energije,
- potreba da se u kratkom vremenu razradi trogodišnji plan razvoja i izgradnje u novom okružju i po novoj metodologiji (problem okvira i temeljnih odrednica za donošenje plana u znatno restrukturiranom okružju u koji se uvode tržišni odnosi, stvaraju pretpostavke za regulirani pristup trećih strana mrežama i uslugama sustava, ulaze novi sudionici, stvara novo poticajno okružje za veće korištenje obnovljivih izvora energije, jednom riječju mijenjaju dosadašnji tradicionalni odnosi i struktura odgovornosti),
- kako napraviti djelotvornu analizu osjetljivosti cijene za korištenje prijenosne mreže, koja sada postaje zasebna stavka,
- kako osigurati pomoćne usluge sustava i na razvidan i pravedan način pridijeliti ih korisnicima i naplatiti,
- kako obuhvatiti i na djelotvoran način analizirati utjecaj vjetroelektrana i drugih postrojenja koja koriste obnovljive izvore energije na pogonske parametre mreže, ali i na troškove korištenja prijenosne mreže,
- kako ustanoviti djelotvoran mehanizam proračuna troškova upravljanja zagušenjima mreže,
- da li ustanoviti odvojeno računovodstvo i kako, itd.

Glede distribucije električne energije, bolje rečeno HEP Operatora distribucijskog sustava problematiku pristupa regulaciji i tarifnom sustavu dodatno prati problematika nestandardnih usluga: njihova

Regarding the transmission of electricity, better to say the HEP Transmission System Operator, the problem of the approach to regulation, i.e. the tariff system, is further complicated by questions and problems of the new environment, including the following:

- the operations of the HEP Transmission System Operator on the open market,
- the manner of the determination and treatment of costs occurring due to the cross-border transit of electricity,
- the necessity of preparing a three-year development and construction plan in a short time within the new environment and according to new methodology (the problem of the framework and fundamental determinants for the adoption of the plan in the significantly restructured environment into which market relations are being introduced, creating the prerequisites for the regulated access of third parties to the system networks and services, the entry of new participants, the creation of a new incentive environment for the increased use of renewable energy sources, i.e. the traditional relationships and structure of responsibilities are changing),
- how to prepare an effective analysis of price sensitivity for the use of the transmission network, which presently represents a separate item,
- how to secure auxiliary system services, allocate them to users and charge for them in a transparent and fair manner,
- how to include and efficiently analyze the impact of wind power plants and other facilities that use renewable energy sources on the network operating parameters, but also on the costs of using the transmission network,
- how to establish an efficient mechanism for calculating the costs of the management of network congestion,
- whether and how to establish separate accounting etc.

Regarding the distribution of electricity, better to say the HEP Distribution System Operator, the problem of

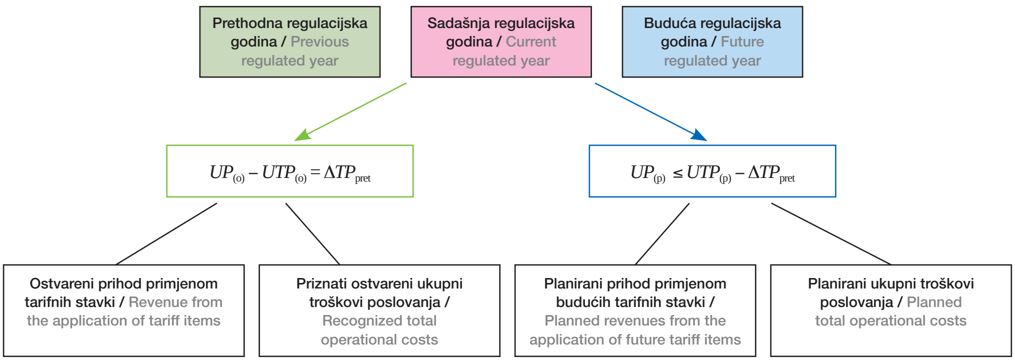
knjigovodstvenog praćenja po izdvojenim kontima i njihova odvajanja od standardnih usluga kod praćenja troškova. Problem je i rasporeda troškova prema njihovoj vrsti te utvrđivanja elemenata za proračun povrata na reguliranu imovinu.

Tijek procesa utvrđivanja i predlaganja visine tarifnih stavki prikazan je na slici 9.

the approach to the regulation and tariff system is additionally accompanied by the problem of nonstandard services; bookkeeping records according to separate accounts and their separation from "standard" services in monitoring expenditures. There is also the problem of the distribution of expenditures according to their type and the determination of the elements for the calculation of returns on regulated property.

The process for the determination and proposal of the amounts of the tariff items is presented in Figure 9.

**Slika 9**
Novi tarifni sustavi (proces predlaganja visine tarifnih stavki)
**Figure 9**
New tariff systems (the process of proposing the amounts of tariff items)




Prethodna godina je godina koja prethodi godini za koju se donose tarifne stavke za odgovarajuću energetsku djelatnost, a za koju su revidirani i objavljeni financijski podaci, poznat ukupni prihod primjenom vrijedećih tarifnih stavki i poznati ostvareni ukupni troškovi poslovanja. Sadašnja regulacijska godina je tekuća godina u kojoj se podnosi prijedlog promjene visine tarifnih stavki za buduću regulacijsku godinu. Prijedlog promjene visine tarifnih stavki za odgovarajuću energetsku djelatnost podnosi energetski subjekt na koji se te tarifne stavke odnose. Energetski subjekt dužan je uz prijedlog za promjenu visine tarifnih stavki dostaviti sve podatke potrebne za utvrđivanje troškova poslovanja, posebno financijsko izvješće za prethodnu regulacijsku godinu potvrđeno od ovlaštenog neovisnog revizora te plan poslovanja i plan razvoja i izgradnje (za sadašnju i buduću regulacijsku godinu). Navedeni dokumenti moraju biti potpisani od ovlaštene osobe energetskog subjekta i ovjereni pečatom tvrtke. Na zahtjev Ministarstva ili Agencije energetski subjekt dužan je dostaviti i druge podatke potrebne za utvrđivanje promjene visine tarifnih stavki te omogućiti uvid u pripadnu dokumentaciju. Prijedlog promjene visine tarifnih stavki za buduću regulacijsku godinu energetski subjekt dužan je dostaviti u sadašnjoj regulacijskoj godini, a nakon što za nju budu po-

The previous year is the year that precedes the year for which tariff items are adopted for the corresponding energy activity, and for which the financial data are revised and published: the known total revenue through the application of the valid tariff items and the known realized total operational costs. The current regulatory year is the current year in which a proposal is submitted for changing the amount of tariff items for the subsequent regulatory year. A proposal for a change in the amount of tariff items for the corresponding energy activity is submitted by an energy entity to which the tariff items apply. Together with the proposal for the change in the amount of tariff items, the energy entity is required to submit all data necessary for the determination of the operational costs, especially the financial report for the previous regulatory year audited by an authorized independent auditor, a plan of operations, and a plan of development and construction (for the current and future regulatory years). These documents must be signed by the authorized person of the energy entity and stamped with the company seal. At the request of the Ministry or Agency, the energy entity is required to submit other data necessary for determining the changes in the amounts of tariff items and facilitate the inspection of the corresponding documentation. A proposal for changes in the amount of tariff items for the subsequent regulatory year must be submit-

znati polugodišnji ukupni troškovi poslovanja. I konačno, energetski subjekt dužan je predložiti promjenu visine tarifnih stavki uz uvjet da očekivani prihod u budućoj regulacijskoj godini, izračunat prema odgovarajućem tarifnog sustava, ne prelazi prihvaćene planirane ukupne troškove poslovanja, korigirane za eventualna opravdana ili odobrena odstupanja.

Pored prethodnog bitno je istaći da su utvrđene i sljedeće obveze energetskih subjekata:

- rok za usklađivanje poslovanja s odredbama tarifnog sustava je šest mjeseci,
- obveza dostavljanja podataka, posebno plana poslovanja te plan razvoja i izgradnje, odnosno trogodišnjeg plana razvoja i izgradnje, kojeg subjekt donosi uz suglasnost Agencije, i to:
  - do 31. 5. sadašnje regulacijske godine – financijska izvješća za prethodnu regulacijsku godinu potvrđena od ovlaštenog neovisnog revizora,
  - do 30.11. sadašnje regulacijske godine - planovi poslovanja.

## 4 ZAKLJUČCI OKRUGLOG STOLA O ULOZI REGULATORNOG TIJELA U DONOŠENJU TARIFNIH SUSTAVA

Nakon svih prezentacija i rasprava u kojima su sudjelovali predstavnici regulatornih tijela iz Francuske, Austrije, Slovenije, Mađarske i Hrvatske, te predstavnici Hrvatske elektroprivrede d.d., odnosno predstavnici energetskih subjekta u Republici Hrvatskoj za koje se donose i primjenjuju odgovarajući tarifni sustavi, utvrđeni su zaključci Okruglog stola. Ti zaključci su bili kako slijedi:

1) Okrugli stol uspješno je organiziran i proveden i u potpunosti je opravdao razloge organiziranja, ponudivši niz odgovora na važna pitanja i dileme glede pristupa, sadržaja i forme regulacije, provedbenih procedura i metodologija regulacije, metodologija tarifnih sustava i strukture samih tarifnih stavki. Naravno, sudionici nisu propustili naglasiti i pojasniti niz provedbenih ili proceduralnih, dakle pojavnih i praktičnih problema s kojima se susreću regulatorna tijela i regulirani energetski subjekti, naročito oni koji su nositelji monopolnih djelatnosti i obveza javnih usluga.

2) Predavači su sudionike Okruglog stola uveli u predmetnu problematiku i ukazali im na opću prisutnost sličnih pitanja i dilema u svim zemlja-

ted by an energy entity during the current regulatory year, and after it knows the total operational costs for the first half of the year. Finally, the energy entity is required to propose a change in the amount of tariff items under the condition that the anticipated revenue in the subsequent regulatory year, calculated according to the corresponding tariff system, does not exceed the accepted planned total operational costs, corrected for eventual justified or authorized discrepancies.

In addition to the above, it is essential to emphasize that the following obligations of energy entities have also been determined:

- the deadline for the coordination of operations with the provisions of the tariff system is six months,
- the obligation for the submission of data, especially a plan of operations and a plan for development and construction, i.e. a three-year plan for development and construction, that the subject adopts with the approval of the Agency, as follows:
  - by May 31 of the current regulatory year – financial reports for the previous regulatory year that have been audited by an authorized independent auditor, and
  - by November 30 of the current regulatory year – operational plans.

## 4 CONCLUSIONS OF THE ROUND TABLE DISCUSSION ON THE ROLE OF THE REGULATORY BODY IN THE ADOPTION OF NEW TARIFF SYSTEMS

Following all the presentations and discussions in which the participants were the representatives of the regulatory agencies of France, Austria, Slovenia, Hungary and Croatia; representatives of Hrvatska elektroprivreda d.d., and representatives of the energy entities in the Republic of Croatia for whom the corresponding tariff systems are being adopted and applied, conclusions were reached by the Round Table, as follows:

1) The Round Table was organized and conducted successfully. It fully justified the reasons for which it was held, providing a range of answers to important issues and dilemmas related to the approach, regulatory contents and form, implemented procedures, regulatory methodology, tariff system methodology and the structure of the tariff items themselves. The participants emphasized and explained a range of implementational or procedural issues, i.e. actual and practical issues that the regulatory agencies and regulated entities encounter, especially those with monopolies and public service obligations.

ma, kod svih regulatornih tijela i svih reguliranih energetskih subjekata. Naravno, u zemljama u kojima su odgovarajuća energetska regulatorna tijela osnovana tek nedavno, u kojima određeni procesi restrukturiranja i novog organiziranja elektroenergetskog sektora nisu u potpunosti dovršeni, u kojima je proces otvaranja tržišta električne energije i uvođenje konkurencije tek u početnoj fazi, i konačno u kojima odgovarajuće makroekonomske pokazatelje i utjecajne regulatorne parametre nije nimalo lako i jednostavno utvrditi, puno je veći broj i pitanja i dilema. Oblik prenošenja znanja i stečenih iskustava, kakav je uostalom ponudio i ovaj Okrugli stol, ukazuje na nužnost i potrebu organizacije istih ili sličnih formi i sadržaja rada na nacionalnoj, regionalnoj, pa i široj međunarodnoj razini, bilo da se radi o okruglim stolovima, radionicama, seminarima ili konferencijama.

3) Okrugli stol naglasio je da je bez obzira na različita iskustva i dinamiku procesa, i bez obzira na opći zakonodavni i gospodarski sustav iz kojeg dolazi, odgovarajući vrijedeći zakonodavni okvir u svakoj državi mora osigurati uvjete za nezavisan, nepristran i razvidan rad energetskog regulatornog tijela. Unutar toga zakonodavnog okvira nadležno državno tijelo i regulatorno tijelo imaju obvezu i dužnost izgraditi i primijeniti utemeljene, realne, razvidne i lako provedive mehanizme i metodologije regulacije, odnosno metodologije tarifnih sustava. O raznim oblicima ili sadržajima, političkim i gospodarskim utjecajima nužno je voditi računa utoliko što su oni stalno prisutni, što su izrazi raznih nacionalnih strategija ili interesa, dakle predstavljanju važan element realnog okružja u kojem se odvija život i rad regulatornog tijela i reguliranih energetskih subjekata, i u kojem se uspostavlja tržište električne energije.

4) Okrugli stol naglasio je suštinsku uvjetovanost problema regulacije reguliranih energetskih djelatnosti, naročito monopolnih mrežnih sustava i javnih usluga dinamikom otvaranja i načinom uređenja tržišta električne energije. Pravo pristupa mrežama i pomoćnim uslugama sustava prvo je u nizu problema s kojima se treba susresti. Nema dvojbe da se pravo pristupa treba i mora urediti unaprijed kroz odgovarajuća mrežna pravila i tehničke uvjete, ali da bi se moglo ostvarivati u nepristranom, razvidno i nediskriminirajućem okružju, nužno je unaprijed utvrditi i objaviti i tehničke i ekonomske uvjete priključka i naknade za korištenja prijenosne i distribucijske mreže, te uvjete i naknade za korištenje pomoćnih usluga sustava, naravno u slučaju da su iste obuhvaćene odgovarajućim regulatornim okvirom.

5) Okrugli stol jasno je pokazao prednost u iskustvu i rješenjima regulatornih tijela, odnosno

2) The lecturers introduced the issues to the Round Table Discussion participants and called attention to the general presence of similar questions and dilemmas in all the countries, regulatory agencies and regulated electrical power entities. Naturally, there are many more questions and dilemmas in countries where the energy regulatory agencies have only been recently established and certain processes of the restructuring and reorganizing of the electricity sector have not been fully completed, where the processes of opening the electricity market and the introducing of competition are in the initial phases and, finally, where the corresponding macro-economic indices and influential regulatory parameters are not easy to determine. The form of the transfer of knowledge and acquired experience, as provided at this Round Table Discussion, indicates the necessity for organizing similar events at the national, regional and even international levels, in the form of round table discussions, workshops, seminars or conferences.

3) The Round Table Discussion emphasized that, regardless of differences in experiences and process dynamics, and regardless of the general legal and economic system, the appropriate valid and transparent legal framework in each country must provide conditions for the independent, nondiscriminatory and transparent operation of the energy regulatory agency. Within this legal framework, the authorized government agency and regulatory agency have the obligation and duty to build and implement well-founded, realistic, transparent and feasible regulatory mechanisms and tariff system methodologies. It is necessary to take the various forms and contents of the prevailing political and economic influences into account, which are expressions of various national strategies or interests, i.e. they represent an important element of the actual environment in which the regulatory agency and the regulated electrical power entities function, and in which the electricity market is established.

4) The Round Table Discussion highlighted an essential correlation among the issues of the regulation of regulated activities, especially monopolistic network systems and public services, in the dynamics of the opening of electricity markets and the manner of their organization. The right to access the networks and auxiliary services of the system is the first in a series of issues that must be addressed. There is no doubt that the right to access must be defined in advance through appropriate network rules and technical conditions. In order for this right to be exercised in an nondiscriminatory, transparent and non-discriminatory environment, it is necessary to predetermine and publish the technical and economic prerequisites for electricity connections, charges for using the transmission and distribution networks, and the conditions and charges for the use of the

država i njihovih odgovarajućih energetskih sektora i gospodarskih subjekata, koji su u spomenute procese i problematiku ušli ranije. S druge strane, prednost zemalja, njihovih energetskih sustava i gospodarstava, dakako i njihovih regulatornih tijela, koji su procese otvaranja tržišta električne energije i uvođenja novih oblika regulacije započeli tek nedavno, da mogu koristiti odgovarajuća iskustva zemalja u kojima su tržišta električne energije uspostavljena i razvijena ranije, i kojima je regulacija ušla u više faze i razdoblja primjene, pri tom ne ponavljajući njihove zablude i kriva rješenja.

6) U pogledu regulacije energetskih djelatnosti prednost je država i ekonomija, uključujući i energetski sektor, koji imaju dobro praćenje i izvještavanje o adekvatnim makroekonomskim gospodarskim parametrima, kao što su interesne, odnosno kamatne stope na vlastiti kapital i zaduženja, stope inflacije, premije na tržišne rizike, prinose od rizičnih i nerizičnih ulaganja, pokazatelje u svezi s prinosom dionica, premije za tržišni rizik vlastitog kapitala itd. Jednoznačni prijenos i primjena navedenih parametara iz jednog nacionalnog u drugi nacionalni energetski gospodarski sustav ili regulatorni okvir vrlo je dvojben i prati ga niz pitanja i dvojbi. Tim više što ne samo da nema jednoznačnih kriterija, nego su i vrlo različiti pristupi utvrđivanju osnovica, npr. vrijednosti imovine i regulatorne osnovice, na koje se navedeni parametri primjenjuju. U tom kontekstu i ciljani financijski pokazatelji, kao što je to npr. stopa povrata na imovinu ili pak garantirani vremenski rok povrata uloženih sredstava, u posljednje vrijeme sve češće postaju predmetom preispitivanja, nerijetko čak i važno političko pitanje na nacionalnoj razini. Naime, s navedenim pitanjima usko su povezani problemi novih investicija i ulaganja u elektroenergetske sustave, ali i pitanja profita iz energetskih djelatnosti. Svaki od navedenih ekonomskih veličina i parametara dakako ima svoj odraz u odgovarajućem utjecaju na ekonomičnost poslovanja energetskog subjekta i njegovu sposobnost da se dalje razvija.

U okviru diskusije konstatirano je da bi bilo dobro i pragmatično da prve razvojne faze ekonomske regulacije prate i relativno jednostavne regulacijske sheme tipa *cost plus* ili povrata sredstava, da bi nakon stjecanja određenih iskustava i znanja uslijedio razvoj puno složenijih shema koje uključuju kombinacije tehničkih i ekonomskih inicijativa koje kroz dugoročni period trebaju osigurati sigurno i stabilno financiranje rada i adekvatni razvoj reguliranih energetskih subjekta, naročito velikih mrežnih infrastrukturnih sustava za prijenos i distribuciju električne energije. Opći konačni cilj je dakako sigurna opskrba električnom energijom po realnoj, odnosno opravdanoj cijeni.

auxiliary system services in the event that these are covered by the corresponding regulatory framework.

5) The Round Table Discussion clearly demonstrated the superiority of the experience and solutions of the regulatory bodies, countries, energy sectors and economic entities which had addressed these processes and problems earlier. On the other hand, the countries, energy systems, economies and certainly regulatory agencies that have only begun the processes of opening the electricity markets and introducing new forms of regulations have the advantage of being able to utilize the experiences and avoid repeating the past errors and inadequate solutions of the countries in which the electricity markets have already been established and developed, and in which regulations have entered advanced phases and periods of application.

6) In the regulation of energy activities, the governments and economies, including the energy sectors, that have good tracking and reporting of macroeconomic parameters such as interest rates on equity and debt, inflation rates, market risk premiums, yields from high-risk and low-risk investments, indices in connection with stock market yields, equity-risk premiums etc. are at an advantage. The direct transfer and application of these parameters from one national power system or regulatory framework to another is not practicable because a number of issues and dilemmas are involved. This is even more the case because there are no uniform criteria. Instead, there are highly varied approaches for the determination of the bases, for example the asset-value base and regulatory base to which the given parameters are applied.

In this context, the target financial indices such as the rate of return on assets or the guaranteed period of return on investment have lately become subjected to increasing scrutiny and are frequently an important political issue at the national level. Closely related to these issues are the problems of new investments in power systems, as well as the question of profit from electricity activities. Each of these economic measurements and parameters certainly influence the cost-effectiveness of the operations of entities and their ability to continue to develop.

Within the framework of the discussion, it was concluded that it would be good and pragmatic for the first development phases of economic regulation to accompany relatively simple regulation schemes of the “cost plus” or “return on assets” type. After experience and knowledge are acquired, this should be followed by the development of more complex schemes that include a combination of technical and economic initiatives, which over the long run should assure the secure and stable financing of operations

7) Regulatorna tijela imaju važnu ulogu u procesu odobravanja i nadzora provedbe razvojnih planova reguliranih subjekata, tj. prijenosne i distribucijske mreže i sustava, odnosno nadzornu ulogu u pogledu kvalitete i sigurnosti usluga i funkcija koje obavljaju ti energetski subjekti, ali i opskrbe krajnjih kupaca i korisnika u cjelini. Pristupi i praksa u različitim zemljama razlikuju se.

Ima primjera duboke uključenosti i odgovornosti regulatornog tijela u svim fazama i elementima planiranja (odobravanje i nadzor provedbe planova), osiguranja sredstava kroz naknade i poticajne elemente tih naknada (kapitalni troškovi, povrati na kapital), te općeg procesa nadzora rada reguliranog energetskog subjekta. S druge strane, uloge nekih regulatornih tijela u početku nisu podrazumijevala obilježja duboke uključenosti. Nadomjestak dubljem regulatornom nadzoru bili su opći pristupi po kojim su npr. planirane investicije iz razvojnih planova i planova izgradnje bile odobravane do određene razine i kao takve uključene u naknade za korištenje mreže. Ima primjera i manje involviranosti regulatornog tijela u početnim fazama uvođenja regulacije ili tijekom početnih regulatornih perioda. Međutim, odmakom procesa i sve većom involviranosti regulatornog tijela u više slučajeva dovelo je do smanjenja naknada za korištenje mreža.

8) Navedeni tijek gotovo u potpunosti poklapa se s tijekom uvođenja složenih regulatornih pristupa i metodologija ekonomske regulacije, odnosno metoda poticajne regulacije energetskih djelatnosti. Iz svega prethodnog izveden je zaključak da se u početku trebaju što bolje i preciznije definirati odgovornosti regulatornog tijela i reguliranih subjekata. Nadalje, u novonastalim i tržišnim okolnostima trebaju se dobro obuhvatiti i obrazložiti svi važni parametri, utjecajne veličine i okolnosti tržišnog okružja koje se uvodi, Posebno je važno krenuti s jednostavnijim regulatornim pristupima i metodama, i to u pravilu s kraćim regulatornim periodima. Svaka od mogućih nesigurnosti ili skrivenih mana u regulatornom pristupu, krivo procijenjenog utjecajnog parametra ili ciljanog ekonomskog indeksa, nepredviđene loše posljedice procesa restrukturiranja u dinamičnom tržišnom okružju, ali na kraju i posljedice moguće krive odluke regulatornog tijela, vodi ili vrlo visokim ili nedopustivo niskim iznosima naknada za korištenje mreža. Visoki iznosi naknada za korištenje mreža znače ne samo visoke troškove za korisnike mreža, nego, pogotovo za one izvan dosadašnjih integriranih nacionalnih elektroenergetskih sustava, i značajnu prepreku za ulazak na tržište električne energije, a time i njegovom razvoju. Iskazani neopravdano visoki iznosi profita u monopolnim djelatnostima imaju i daljnje negativne političke i socijalne posljedice, čak,

and the adequate development of the regulated energy entities, especially the large network infrastructure systems for the transmission and distribution of electricity. The general goal is, of course, a secure supply of electricity at a realistic, i.e. justified, cost.

7) The regulatory agencies have an important role in the process of the authorization and supervision of the implementation of the plans for the development of the regulated entities, i.e. the transmission and distribution networks and systems, and a supervisory role over the quality and security of the services and functions performed by these energy entities, as well as supply to the end users and users in general. The approaches and practices in various countries differ.

There are regulatory agencies that are deeply involved in and responsible for all the phases and elements of planning (the authorization and supervision of plan implementation), obtaining funds through charges and the incentive elements of these charges (capital expenditures, return on equity) and the general supervisory process of the operations of a regulated entity. On the other hand, initially the roles of some of the regulatory agencies were not characterized by deep involvement. Instead of in-depth regulatory supervision, there were general approaches according to which, for example, planned investments from development and construction plans were approved up to a specified level and as such included in the charges for network use. There are examples of less involvement by a regulatory agency during the initial phases of the introduction of regulation or during the initial regulatory periods. However, as the processes progressed and the regulatory agencies became increasingly involved in an increasing number of cases, in many cases the charges for network use dropped.

8) This nearly completely corresponds with the introduction of more complex regulatory approaches and methodologies of economic regulation, i.e. methods of the incentive regulation of activities. From the aforementioned, it was concluded that at the beginning it is necessary to define the responsibilities of the regulatory agency and the regulated entities as precisely as possible. Furthermore, under the newly arisen market circumstances, it is necessary to include and explain all the important parameters, influential values and market environment circumstances that are being introduced. It is especially important to start with simple regulatory approaches and methods and, as a rule, with short regulatory periods. Any of the potential uncertainties or hidden flaws in a regulatory approach, an incorrectly estimated influential parameter or a target economic index, the unforeseen negative consequences of the restructuring process in a dynamic market environment, or the ultimate consequences of any wrong decisions by the regulatory agency may lead either

ili naročito u slučajevima kada su državna tijela te profite oduzela energetskim subjektima. S druge strane, niski ili nedovoljno visoki iznosi naknada za korištenje mreža direktno ugrožavaju poslovanje energetskih subjekata, kvalitetu usluga i funkcija koje ti subjekti pružaju, a ako takvo stanje traje duže, onda i tehničko-tehnološke osobine same mreže i sustava.

Konačan zaključak u pogledu prethodnog bio je da bez obzira na uzroke, svaki problem i svaka posljedica prenosi se na korisnika ili krajnjeg kupca i postaju njegov problem, a obveza je i energetskog subjekta i regulatornog tijela da u reguliranom okružju te probleme i posljedice otklone. Najefikasnijim općim pristupom otklanjanja svih negativnih posljedica ocjenjuje se pragmatični pristup i postupanje, a ako je moguće i suradnja sve tri zainteresirane strane.

9) Poseban problem i izazov predstavlja regulacija mrežnih infrastrukturnih monopola, prijenosa i distribucije, te u svezi s tim usko povezani problem gdje i pod kojim uvjetima se osiguravaju pomoćne usluge sustava. Naročito se u segmentu pomoćnih usluga sustava mogu pojaviti dominantne pozicije i zlouporabe u još uvijek značajno integriranim sustavima, kada se poduzećima iz sustava ili grupe osiguravaju povoljniji uvjeti pristupa i korištenja pomoćnih usluga ili njihova plaćanja. U sprječavanju takvih situacija, štoviše njihova sankcioniranja, presudna je uloga regulatornih tijela.

Problem pomoćnih usluga i odgovornosti za njihovo osiguranje i pružanje usko je vezan s postojećim zakonodavnim i regulatornim okvirom, ili općenito pitanjem da li se na taj segment primjenjuje regulirani ili tržišni kontekst. U svakom slučaju, u svezi s tim segmentom najviše je pitanja i dilema. Pitanje je i kojoj djelatnosti iz dosadašnje integrirane strukture i jedinstvene tarife koja je uključivala sve djelatnosti i usluge pridijeliti odgovornost za osiguranje pomoćnih usluga, i kako te usluge naplatiti, kao dio odgovarajućih naknada ili zasebno. Neke zemlje taj problem razriješile su pridjeljujući obveze i funkcije osiguranja pomoćnih usluga operatorima prijenosnih i distribucijskih sustava, odnosno uvodeći ugovorne odnose po kojima tržišni sudionici i te usluge slobodno ugovaraju, osiguravaju i na kraju plaćaju. No, istaknuto je, da su takva rješenja i mehanizmi bili moguće tek nakon što je uspostavljena cjelovita funkcionalna i provedbena shema osiguravanja, tj. izvora i pridjeljivanja svake pojedinačne pomoćne usluge ili njene komponente, ali i uvjeta njihova eventualnog prekida i posljedica toga prekida. Činjenica je da su u nekim zemljama, a radi se o zemljama i energetskim gospodarstvima koja su u pravilu u ranim fazama procesa restrukturiranja, otvaranja

to very high or inadmissibly low charges for network use. High charges for network use would not only mean high costs for network users but would also pose a significant barrier to entry into the electricity market and development by those entities outside the current integrated national power systems. The unreasonably high profits of monopolies have further negative political and social consequences, even or especially in cases when government agencies have redirected these earnings away from the entities. On the other hand, low or insufficient charges for network use directly jeopardize the operations of entities, the quality of the services and functions provided by these entities and, if such conditions persist for extended periods, they may also jeopardize the technical and technological characteristics of the network and system.

The final conclusion in respect to the above is that regardless of the cause, each problem and consequence is shifted to the user or the final customers and becomes their problem. Both the entity and the regulatory agency should resolve these issues within the regulated environment and eliminate the consequences. The most efficient general approach to eliminating all such negative consequences is thought to be a pragmatic one, together with cooperation among all three interested parties, if possible.

9) A separate problem and challenge is the regulation of the network infrastructure monopolies, transmission and distribution and, closely connected to this, the issue of where and under which circumstances auxiliary system services should be provided. Especially in the segment of auxiliary services of the system, dominant positions and abuses may occur in systems that are still significantly integrated when enterprises from the system or groups are provided with more favorable conditions for accessing, using or paying for auxiliary services. In order to prevent such situations, moreover to penalize them, the role of the regulatory agencies is crucial.

The issue of auxiliary services and the responsibility for providing them are closely connected to the existing legislative and regulatory frameworks or, in general, to the question whether the regulated or market context should be applied to this segment. In any case, the most questions and dilemmas are associated with this segment. It is a question as to which activities from the current integrated structure and single tariff that included all the activities and services should be assigned responsibility for securing auxiliary services, and how should these services be charged, as a part of the corresponding charges or separately. Some countries have resolved this problem by assigning the obligations and functions for securing auxiliary services to the transmission and distribution system operators, or by introduc-

tržišta, odnosno razvoja i uspostave odgovarajućeg regulatornog okružja, pitanja i problemi uspostave cjelovitog sustava osiguravanja, korištenja, pridjeljivanja i plaćanja pomoćnih usluga sustava još uvijek samo naznačeni ili tek u ranim fazama rješavanja. U svakom slučaju neriješena pitanja i problemi u svezi s pomoćnim uslugama sustava znatno otežavaju razvidnost i efikasnost procesa otvaranja tržišta električne energije u svim njegovim ključnim sastavnicama, a naročito u pogledu osiguranja uvjeta za razvidan, nepristran i pravedan pristup mrežama i sustavima. Takvo stanje ima daljnje negativne posljedice po razvoj i uvođenje novih metoda regulacije i metodologija tarifnih sustava, što posljedično i regulatorno tijelo dovodi u puno teži položaj i ugrožava njegovu vjerodostojnost suočavajući ga s objektivno teškim problemom izbora pristupa i metodologije, ali i reakcijom energetskih subjekata i tržišnih sudionika.

U pravilu, stav je da u reguliranom kontekstu osiguranje i pružanje tih usluga treba biti jedna od funkcija i obveza operatora prijenosnog i distribucijskog sustava, koja je po unaprijed poznatim uvjetima, na razvidan, nepristran i nediskriminirajući način dostupna i pridjeljuje se korisnicima elektroenergetskih mreža i sustava. Zaključak je da razina cijena, odnosno tarifa za pomoćne usluge sustava treba biti troškovno utemeljena i razvidna u svim njegovim elementima. Tijekom rasprave istaknuto je da postoji i problem osiguranja određenih pomoćnih usluga od strane starih proizvodnih postrojenja. Kod postavljanja tržišnog modela o tom se mora voditi računa, naročito kod tržišnih modela koji podrazumijevaju mogućnost pristupa pojedinačnih proizvodnih postrojenja tržištu i njihove participacije na tržištu kao samostalnih tržišnih sudionika. Regulatorna tijela i operatori sustava o tim pitanjima i problemima moraju voditi računa u svim segmentima procesa definiranja tržišnog modela, regulatornog okvira i modela, provedbenih procedura, a ako je kontekst pomoćnih usluga sustava regulirani, onda i metodologiji utvrđivanja tarifnih stavki i proceduri ugovaranja i osiguravanja pomoćnih usluga sustava.

10) Ključnim ciljevima regulacije energetskih djelatnosti, naročito prijenosa i distribucije električne energije smatraju se uspostava nepristranog i razvidnog pristupa mreži, pokriće opravdanih troškova poslovanja, nastojanja da se unaprijedi efikasnost sektora i/ili da se sektor učini privlačnim za nove investicije, odnosno ulaganja. Odgovarajući izvori financiranja mogu se osigurati bilo neposredno kroz naknade za priključak i korištenje mreža, bilo kroz odgovarajuće poticajne uvjete i povrate na investicije, odnosno od i imovinu energetskog subjekta. Postupke i

ing contractual relations on the basis of which the market participants freely contract, provide and at the end pay for these services. However, it has been pointed out that such solutions and mechanisms are only possible after the entire functional and implementation scheme is established, i.e. the source and assignment of each individual auxiliary service or component thereof, as well as the conditions for their eventual termination and the consequences of such termination. The fact is that in some countries, mainly countries and electrical energy economies which are in the early phases of restructuring, market opening and developing an appropriate regulatory environment, the issues and problems of the establishment of the overall system for the provision, use, allocation and payment of auxiliary services are still only on paper or in the early phases of solution. In any case, the unresolved issues and problems in connection with auxiliary system services significantly diminish the transparency and efficiency of the opening of electricity markets in all the key elements, especially regarding the providing of the conditions for the transparent, nondiscriminatory and fair access to networks and systems. Such a situation has further negative consequences upon the development and introduction of new regulatory methods and methodologies of the tariff systems, which consequently place the regulatory agency in a far more difficult position and threaten its credibility, confronting it with the difficult problem of choosing an approach and methodology, as well as the reactions of the entities and market participants.

In principle, the position is that in the regulated context, providing these services should be one of the functions and obligations of the transmission and distribution system operators, which, under predetermined conditions should be available and assigned to users of electricity networks and systems in a transparent, nondiscriminatory and non-discriminatory manner. The conclusion is that the level of prices, i.e. tariffs for the auxiliary services of a system, should be cost-based and transparent in all elements. During the discussion, it was emphasized that there is also the problem of securing certain auxiliary services from the old power-generation facilities. When setting up a market model, this must be taken into account, especially with market models that include the option of access by individual power-generation facilities to the market, and their status as independent market participants. The regulatory agencies and system operators must take these issues and questions into account in all the segments of the process of the definition of a market model, regulatory framework and model, and implementation procedures. If the context of auxiliary system services is regulated, this also means taking into account the methodology for establishing tariff items and procedures for the contracting and providing of auxiliary system services.

metode regulacije i metodologije tarifnih sustava u tom pogledu nužno je stalno dograđivati i unaprjeđivati. U tom pogledu, regulatorno tijelo ima primarni zadatak, ali s obzirom na to da opskrba električnom energijom ostaje i nadalje aktivnost visokog socijalnog i gospodarskog značenja, u rad na predmetnoj problematici trebaju biti uključena poduzeća iz energetskog sektora, tijela državne uprave i druge državne institucije, stručna i ostala javnost, te organizacije za zaštitu interesa potrošača, sindikati i financijske institucije. Sve više je dokaza u prilog opće važnosti koje predmetnoj problematici posvećuju sve navedene stranke.

**11)** Regulatorno tijelo treba imati kontrolu nad svim segmentima regulacijskog razdoblja. Naročito se to odnosi na pripremno razdoblje u kojem bi regulatorno tijelo trebalo biti aktivno uključeno, uz regulirani subjekt. Odnosi se to na pregled ulaznih podataka, podloga i parametara koje se koriste, njihovu obradu, kao i rokove u kojima se pojedini segment pripremne faze za uvođenje metode regulacije mora provesti. U prilog tome govore i odgovarajuća iskustva nekih zemalja.

**12)** U prethodnom kontekstu, u socijalnom, političkom i gospodarskom smislu u svezi sa stabilnošću i sigurnošću opskrbe svakako je dobro izbjegavati velike i nagle skokove u promjenama cijena, nepredvidive ili nenajavljene promjene cijena. U pogledu mogućnosti reguliranih energetskih subjekata da razumiju, prilagode se i provedu odgovarajući regulatorni pristup i prilagode poslovanje novom sadržaju koji su iskazani kroz postupke i metode regulacije, svakako je nužna suradnja regulatornog tijela i reguliranih subjekata. Suradnja je i ključni preduvjet potpunog razumijevanja procesa i sadržaja definicije i uspostave određenog okvira i postupka regulacije, i kroz proces utvrđivanja i donošenja odgovarajućih tarifnih stavki, a time i njihova prihvaćanja i dobre provedbe. Uzimajući u obzir i sve druge moguće utjecaje, npr. socijalni i/ili politički, nije naodmet ustvrditi da se nerijetko postupa pragmatično, nastojeći odvagnuti i nastojeći valorizirati doprinos svakog od tih mogućih utjecaja ili ograničavajućih elemenata.

Od regulatornih tijela traži se kvalitetan i efikasan sustav nadzora nad tržištem električne energije, pogotovo sprječavanje ili čak sankcioniranje situacija u kojima se u tzv. integriranim sustavima sredstva prelijevaju iz monopolnih djelatnosti u tržišne djelatnosti, osiguravajući tržišnim djelatnostima znatnu neopravdanu i neprihvatljivu prednost u odnosu na druge tržišne sudionike u tržišnoj utakmici, što je ujedno i direktan oblik zlouporaba neopravdane tržišne pozicije ili snage. Navedeni su i konkretni slučajevi u kojima su u takvim si-

**10)** The key goals of the regulation of energy activities, especially the transmission and distribution of electricity, are to establish nondiscriminatory and transparent access to the network, cover justified operational costs, attempt to improve the efficiency of the sector and/or make the sector attractive for new investments. Suitable sources of financing can be secured either directly through charges for connection to the network, network use or through suitable incentive conditions and returns on investments, i.e. from the assets of the entities. Procedures and methods for the regulation and methodology of the tariff systems must be constantly updated and improved. In this regard, the regulatory agency has the primary task. However, since the supplying of electricity continues to remain an activity of great social and economic significance, enterprises from the energy sector, government administrative agencies, other government institutions, professionals, the general public, organizations for protecting consumer interests, unions and financial institutions should be included in working on this issue. There is increasing evidence of the general importance afforded to this issue by all the aforementioned parties.

**11)** The regulatory agency must have control over all the segments of the regulatory period. This especially refers to the preparatory period in which the regulatory agency should be actively involved, together with the regulated entity. It concerns a review and processing of the input data, bases and parameters used as well as the periods within which the separate segments of the preparatory phase for the implementation of a regulatory method must be completed. The corresponding experiences of some countries underscore this point.

**12)** In the aforementioned context, in the social, political and economic sense, regarding the stability and safety of supply, it is indeed good to avoid large and sudden price changes and unforeseen or unannounced price changes. Regarding the abilities of the regulated energy entities to understand, adapt to and implement the suitable regulatory approach and adjust operations to the new content expressed through the regulatory procedures and methods, cooperation between the regulatory agency and the regulated entities is certainly essential. Cooperation is also a key prerequisite for completely understanding the process and the contents of the definitions and the establishment of certain frameworks and regulatory procedures, both through the process of the determination and adoption of certain tariff items, and through their acceptance and correct implementation. Taking into account any other possible influences, e.g. social and/or political, it is worth mentioning that a pragmatic approach, in which it is attempted to weigh and evaluate the contribution of each of these potential influences or limiting elements, is often employed.

tuacijama regulatorna tijela postupala tako da se umanjila, ili čak oduzela odgovarajući dio prihoda od integriranog poduzeća, i to od segmenta tržišnih djelatnosti, i vratila ga u segment monopolnih, odnosno djelatnosti s obvezama javnih usluga iz kojeg su i bili neopravdano uzeti. U svakom slučaju, dok postoje dvije paralelne komponente tržišta, regulirana i liberalizirana, odnosno tržišna, regulatorno tijelo ima striktnu obvezu provjeravati razvidnost odvajanja pripadajućih računa i prihoda, a nerijetko i pravo da određene oblike ponašanja i prekršaja i jače sankcionira. Čest je slučaj da regulatorno tijelo ima pravo, utemeljeno na zakonu, samo provesti odgovarajući revizorski nadzor, ili taj nadzor zatražiti od nezavisnih revizora.

13) Okrugli stol je raspravio i pitanja strukture naknada za korištenje prijenosne, odnosno distribucijske mreže. Istaknuta je važnost primjene principa da struktura i razina naknada za korištenje mreža odražavaju strukturu troškova za elemente energije i snage, tj. kapaciteta, prema i za koje se utvrđuju. Poglavito je element snage i njegovo vrednovanje važan u strukturi tarifnih stavki, tj. naknada za priključak, za korištenje prijenosne i distribucijske mreže, i naknada za pomoćne usluge sustava. Važnost elementa kapaciteta ogleda se i u vrednovanju u svezi s mehanizmima pridjeljivanjem, korištenjem i plaćanjem odgovarajućih prekograničnih kapaciteta, ili utvrđivanjem odgovornosti, odnosno postupcima rješavanja zagušenja u prijenosnoj i distribucijskoj mreži.

14) U nekim zemljama proces uvođenja novog regulatornog pristupa i primjene novih metodologija ekonomske regulacije koji u pravilu uključuju parametre valorizacije i poticanja učinkovitosti poslovanja reguliranog energetskog subjekta, a nerijetko i odgovarajuće opće makroekonomske indekse za valorizaciju i pokriće adekvatnih rizika poslovanja i ulaganja, rezultirao je u smanjenju naknada za korištenje mreža. Međutim, nije realno očekivati da bi se takav kontekst ponovio u većini drugih zemalja, pogotovo ne u zemljama u kojima su cijene električne energije bile pod jakom socijalnom i političkom kontrolom i u pravilu vrlo niske. Štoviše, u tim zemljama izražena je potreba za novim velikim ulaganjima u održavanje, rekonstrukciju i izgradnju mreža. Razdvajanje i izdvajanje energetskih djelatnosti iz dosadašnjih vertikalno integriranih elektroenergetskih struktura proizvodnje, prijenosa, distribucije i opskrbe električnom energijom, otvaranje tržišta električne energije i pojava novih sudionika na tržištu električne energije, tu potrebu samo su još više naglasili. Nije rijedak slučaj sve češće iskazanih uvjerenja da bez dobrih i efikasnih infrastrukturnih prijenosnih i distribucijskih mreža i sustava ne može biti govora o razvoju efikasnog tržišta električne energije.

The regulatory agencies are required to provide a quality and efficient system of supervising the electricity market, especially to prevent or penalize situations in which funds flow from monopoly activities into market activities in the so-called integrated systems, which affords businesses with market operations a significant unfair and unacceptable advantage over other market participants in market competition, and is a direct form of the abuse of an inequitable market position or power. Specific cases were mentioned in such situations when the regulatory agencies acted to reduce or even confiscate the corresponding portion of the revenues from an integrated company from the segment of market activities and direct them back to the monopoly segment, i.e. the activities having the public service obligation from which they had been unfairly taken. In any case, as long as there are two parallel components of the market, regulated and liberalized, the regulatory agency has the strict obligation to verify the transparency of the separation of the corresponding invoices and revenues, and not infrequently the right to penalize certain forms of behavior and violations severely. The regulatory agency frequently only has the right, pursuant to the law, to conduct a suitable audit or request to have such an audit performed by independent auditors.

13) The Round Table Discussion also included questions regarding the structure of charges for the use of a transmission or distribution network. The importance was stressed of applying the principle that the structure and level of charges for network use should reflect the structure of the costs of the elements of energy and power, i.e. the capacities according to and for which they are determined. The element of power and its valuation are particularly important for the structure of the tariff items, i.e. charges for connection, the use of the transmission and distribution networks and auxiliary system services. The importance of the capacity elements is reflected in the evaluation in connection with mechanisms for capacity allocation, the use and charges for cross-border capacities, or determination of the responsibilities, i.e. the procedures for managing congestion in the transmission and distribution networks.

14) In some countries, the process of introducing a new regulatory approach and the application of new methodologies of economic regulation, which as a rule include the parameters for the evaluation and increased effectiveness of the operations of a regulated power entity and not infrequently the corresponding general macroeconomic indices for the evaluation and coverage of adequate risk operations and investments, have resulted in lowered charges for network use. However, it is not realistic to expect such a context to be repeated in the majority of other countries, especially those where electricity prices

Na spomenuti kontekst ulaganja u održavanje, rekonstrukciju i izgradnju nacionalnih elektroenergetskih mreža, odnosno izgradnje novih visokonaponskih prijenosnih prekograničnih poveznica s drugim zemljama i sustavima sve važniji utjecaj ima regionalni i širi multinacionalni kontekst tržišta i razmjena električne energije. Opća je pojava da prekogranična trgovanja i razmjene energije vrlo brzo rastu, zbog čega su za tranzite i prekogranične razmjene energije uvedeni i primjenjuju se novi opće prihvaćeni kompenzacijski i alokacijski mehanizmi. Isti se već jednoznačno primjenjuju u kontekstu internog europskog tržišta električne energije. Nadalje, prihodi ostvareni prekograničnim razmjenama moraju se tretirati na razvidan i nepristran način. Međutim, unatoč nastojanju da se razvije i uspostavi efikasan, razvidan, nepristran i pravedan, u konačnici i lako provediv sustav i mehanizam, za neke elektroenergetske sustave i nadalje ostaje problem načina utvrđivanja i alokacije troškova za visoke gubitke električne energije. Isto vrijedi i u pogledu adekvatnog dijela pomoćnih usluga sustava. Naime, radi se o onom dijelu dodatnih gubitaka električne energije u nacionalnoj elektroenergetskoj mreži i dijelu dodatnih pomoćnih usluga sustava koji nastaju zbog prolaza ili kružnih tokova energije iz međunarodnih, tj. prekograničnih razmjena energije. Opći je stav da europsko energetsko zakonodavstvo, tj. odgovarajuće direktive i uredbe EU u tom pogledu predstavljaju adekvatan zakonodavni okvir za postupanje svih regulatornih tijela.

**15)** Poseban je problem načina pristupa i dobivanja informacija i podatak koje s jedne strane regulatorno tijelo može tražiti i traži od reguliranih subjekata, a koje s druge strane ti regulirani subjekti mogu i žele dati ili daju regulatornom tijelu. U svakom slučaju razlike, tj, asimetrija informacija, u tom pogledu uvijek su prisutne. Zaključak je da je u svakom slučaju, bilo u pogledu zadovoljavajućeg rješenja, bilo barem dobre ravnoteže između regulatornog tijela i reguliranih energetskih subjekata najbolje i najefikasnije odabrati pragmatična rješenja, po mogućnosti zasnovana na dostupnoj najboljoj i najefikasnijoj međunarodnoj praksi i benchmarku. Prethodno gotovo u potpunosti vrijedi i u pogledu procesa i prakse regulatornog ili revizorskog nadzora.

**16)** Posebno je uočena i istaknuta mogućnost i potreba šire, tj. regionalne elaboracije i rasprave problema sadržaja i forme regulacije, regulatornih pristupa i politike, strukture i sadržaja tarifnih metodologija i samih tarifa, utjecajnih parametara i pokazatelja, naročito ekonomskih i političkih, usporednih *(benchmark)* pristupa i analiza, te svakako veće suradnje i transfera znanja i iskustava.

have been under rigorous social and political control and, as a rule, very low. Moreover, in these countries there is a marked need for major new investments in maintenance, reconstruction and network construction. The separation of energy activities from the heretofore vertically integrated structures of the generation, transmission, distribution and supply of electricity, the opening of the electricity markets and the appearance of new participants on the electricity market further underscore this need. Opinions are frequently voiced that the development of an efficient electricity market is not feasible without a good and efficient infrastructure for the transmission and distribution networks and systems.

In this context, investments in the maintenance, reconstruction and construction of national electrical energy networks or in the construction of new high voltage transmission cross-border connections with other countries and systems have an increasing impact upon the regional and broader multinational context of the markets and the exchange of electricity. The cross-border commerce and exchange of energy is generally growing very rapidly, due to which new commonly accepted compensation and allocation mechanisms have been introduced and applied for the transit and cross-border exchange of energy. Such mechanisms are already being applied uniformly within the context of the internal European electricity market. Furthermore, the revenues from cross-border exchanges must be treated in a transparent and nondiscriminatory manner. However, despite attempts to develop and establish an efficient, transparent, nondiscriminatory, just and, in the final analysis, easily applicable system and mechanism, some energy systems are still confronted with the problem of how to determine and allocate expenditures for high losses of electricity. This concerns the share of the additional electricity losses in the national electrical energy network and the share of the additional auxiliary system services that occur due to transit or circular flows from international, i.e. cross-border, energy exchanges. The general position is that the European energy legislation, i.e. the corresponding directives and regulations of the EU in this respect, represents an adequate legislative framework for the operations of all the regulatory agencies.

**15)** There is a specific problem regarding the manner of accessing and obtaining information and data which a regulatory agency can and does require from regulated entities, and which these regulated entities can and want to provide or do provide to the regulatory agency. In any case, these differences, i.e. information asymmetry, are always present in this regard. The conclusion is that in order to obtain a satisfactory solution or at least a good balance between the regulatory agency and the regulated en-

# 5 ZAKLJUČAK

Okrugli stol o ulozi regulatornog tijela u donošenju tarifnih sustava organiziran je kao mjesto susreta i rasprave eksperata i direktnih sudionika, odnosno zainteresiranih strana u regulacijskom procesu, od predstavnika regulatornih tijela, stručne i znanstvene javnosti, do predstavnika reguliranih subjekata. Okrugli stol bio je vrlo uspješan i u potpunosti je opravdao razloge organiziranja, ponudivši dobru elaboraciju problematike i sadržaja regulacije energetskih djelatnosti, organizacije i nadzora tržišta električnom energijom, a posebno i ciljano uloge regulatornog tijela u donošenju tarifnih sustava. Konačno, Okrugli stol ponudio je i niz odgovora, ali i što je još važnije, sudionike je ili uveo u predmetnu problematiku i ukazao im na opću prisutnost sličnih pitanja i dilema u svim zemljama, od članica EU do zemalja koje će tek postati članice EU, ili im dao odgovore na pitanja i dileme s kojima su došli na Okrugli stol. Bez obzira na različita iskustva i dinamiku procesa, Okrugli stol je pomogao da se identificira i komentira niz izazova i problema s kojima se suočavaju sva regulatorna tijela, ali i sva regulirana poduzeća i energetski subjekti, bez obzira na sustave iz kojih dolaze i kontekst u kojem su nastala i u kojem su se razvijala. Također, uočena je mogućnost i potreba za stalnom elaboracijom i raspravom problema sadržaja i forme regulacije, regulatornih pristupa i politike, strukture i sadržaja tarifnih metodologija i samih tarifa, utjecajnih parametara i pokazatelja, naročito ekonomskih i političkih, usporednih *(benchmark)* pristupa i analiza, te svakako veće suradnje i transfera znanja i iskustava.

Zbog svega prethodnog, cilj i svrha ovog članak bili su širu stručnu i znanstvenu javnost izvijestiti o rezultatima, odnosno tijeku i zaključcima tog Okruglog stola, te eventualno potaći stručnu i znanstvenu raspravu o izloženoj problematici, pa čak potaći organizaciju novih okruglih stolova i rasprava o izloženim pitanjima, problemima, sadržajima, ali i izazovima regulacije energetskih djelatnosti.

ergy entities, it is best and most efficient to choose pragmatic solutions, if possible based upon the best available and most efficient international practices and benchmarks. The aforementioned applies in its entirety to the processes and practices of regulatory or audit supervision.

**16)** We have especially noted and emphasized the possibility and necessity for the broader regional elaboration and discussion of the problems of the contents and forms of regulations, regulatory approaches and policies, the structures and contents of tariff methodologies and the tariffs themselves, influential parameters and indices (especially economic and political), benchmark approaches and analysis, together with greater cooperation and the transfer of knowledge and experiences.

# 5 CONCLUSION

The Round Table Discussion on the role of the regulatory agency in the adoption of tariff systems was organized as place of meeting and discussion among experts and direct participants, i.e. interested parties in the regulatory process, from representatives of the regulatory agencies, the professional and scientific public, to representatives of the regulated entities. The Round Table was highly successful and completely justified the reasons for its organization, providing good elaboration of the issues and contents of the regulations on energy operations, the organization and supervision of the electricity market and, particularly, the planned role for the regulatory agency in the adoption of the tariff systems. Finally, the Round Table Discussion provided a series of answers but, more importantly, introduced the participants to the issue under discussion and demonstrated to them that similar questions and dilemmas are generally present in all countries, from the member countries of the EU to the countries that will become members of the EU, or provided them with answers to the questions and dilemmas that they brought with them to the Round Table. Regardless of the various experiences and process dynamics, the Round Table Discussion helped identify and comment on a series of challenges and problems confronted by all regulatory agencies, as well as all regulated enterprises and energy entities, regardless of the systems from which they come and the context in which they originated and developed. Furthermore, the possibility and need were perceived for the ongoing elaboration and discussion of the problems of the content and form of regulation, regulatory approaches and policies, the structure and content of tariff methodologies and the tariffs themselves, the influential parameters and indices (especially economic and political), benchmark approaches and analysis, and certainly

greater cooperation and the transfer of knowledge and experience.

Due to all the aforementioned, the goal and purpose of this article were to inform the general professional and scientific public about the results and conclusions of this Round Table Discussion, eventually stimulate expert and scientific discussion about the issues presented, and even stimulate the organization of new round tables and discussions on the questions, problems, contents but also the challenges of the regulation of energy operations.

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Uredništvo primilo rukopis:
2007-07-30

Prihvaćeno:
2007-08-13

Manuscript received on:
2007-07-30

Accepted on:
2007-08-13

# REGULATORNA POLITIKA I NJEN UTJECAJ NA PLANOVE RAZVOJA I IZGRADNJE ENERGETSKIH SUBJEKATA KOJI OBAVLJAJU REGULIRANE DJELATNOSTI

# REGULATORY POLICY AND ITS IMPACT ON THE DEVELOPMENT AND CONSTRUCTION PLANS OF ENTITIES PERFORMING REGULATED ACTIVITIES

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Hrvatska energetska regulatorna agencija u prosincu 2006. godine donijela je tarifne sustave bez visine tarifnih stavki za djelatnosti proizvodnje, prijenosa, distribucije i opskrbe električnom energijom. Tarifnim sustavima utvrđena je metoda regulacije koja će se primjenjivati prilikom utvrđivanja iznosa tarifnih stavki za pojedinu djelatnost. Jedan od preduvjeta za donošenje iznosa tarifnih stavki od strane Vlade Republike Hrvatske je donošenje planova razvoja i izgradnje prijenosne i distribucijske mreže od strane energetskih subjekata koji obavljaju regulirane djelatnosti na koje Hrvatska energetska regulatorna agencija daje suglasnost.

In December 2006, the Croatian Energy Regulatory Agency – CERA (Hrvatska energetska regulatorna agencija – HERA) adopted tariff systems without stipulating the amounts of the tariff items for the activities of the generation, transmission, distribution and supply of electrical energy. A regulatory method was established through the tariff systems that will be applied in the determination of the amounts of the tariff items for individual activities. One of the prerequisites for the adoption of the amounts of tariff items by the Government of the Republic of Croatia is the adoption of the development and construction plans of the transmission and distribution networks to which the CERA issues approval.

Ključne riječi: planovi razvoja, regulatorna politika, regulatorno tijelo, regulirani energetski subjekt, tarifni sustavi

Key words: development plans, entity performing regulated activity, regulatory body, regulatory policy, tariff systems

# 1 UVOD

U prosincu 2006. godine Hrvatska energetska regulatorna agencija (HERA) donijela je tarifne sustave, bez visine tarifnih stavki za četiri djelatnosti čija se cijena utvrđuje na regulirani način [1]:

- proizvodnju električne energije s iznimkom povlaštenih kupaca,
- prijenos električne energije,
- distribuciju električne energije,
- opskrbu električnom energijom s iznimkom povlaštenih kupaca.

U navedenim tarifnim sustavima definirana je i regulatorna politika, odnosno metoda ekonomske regulacije, a to je metoda priznatih troškova poslovanja [2] do [5]. U teoretskim razmatranjima regulacije energetskih djelatnosti ova metoda svrstana je u klasični pristup regulaciji poznat i pod nazivom regulacija stopom povrata [6]. Tu metodu regulatorna tijela u državama članicama Europske unije (EU) sve više napuštaju i zamjenjuju metodama poticajne regulacije u kombinaciji s regulacijom kvalitete opskrbe [7], budući da se pokazalo da primjena regulacije stopom povrata potiče podizanje troškova ulaganja iznad onih koje bi subjekti koji obavljaju reguliranu djelatnost snosili da ulažu po kriteriju minimalnih troškova. Pokazalo se da u načelu regulacija stopom povrata postiže suprotan učinak od onog kojeg bi trebala osigurati ekonomska regulacija kroz nezavisno regulatorno tijelo. Ciljevi ekonomske regulacije prvenstveno su [7]:

- poticanje učinkovitosti i povećanje produktivnosti,
- osiguranje primjerene financijske sposobnosti sektora,
- sprječavanje diskriminacije kupaca i energetskih subjekata.

Regulatorna politika prema ulaganjima subjekata koji obavljaju regulirane djelatnosti jedan je od ključnih segmenata u provođenju ekonomske regulacije. Nova ulaganja, ako su prihvaćena kao dozvoljeni trošak, uključena su u regulatornu osnovicu sredstava, kroz amortizaciju i iznos dozvoljenog povrata sredstava. Regulatorno tijelo može imati značajnu ulogu u utvrđivanju opravdane razine ulaganja, a time i u postupku utvrđivanja cijene reguliranih djelatnosti. Tim više, ako se uzme u obzir činjenica da mnoga zakonska rješenja predviđaju da regulatorno tijelo daje suglasnost ili donosi planove razvoja subjekata koji obavljaju regulirane djelatnosti.

# 1 INTRODUCTION

In December 2006, the Croatian Energy Regulatory Agency (CERA) adopted tariff systems without stipulating the amounts of the tariff items for four activities for which the prices are determined in a regulated manner [1]:

- the generation of electrical energy, with the exception of eligible customers,
- the transmission of electrical energy,
- the distribution of electrical energy,
- the supply of electrical energy, with the exception of eligible customers.

In these tariff systems, the regulatory policy, i.e. the method of economic regulation, was defined [2] to [5]. In theoretical studies of the regulation of energy activities, this method is classified in the classical approach to regulation that is known as the rate of return (*RoR*) method [6]. This method is being increasingly abandoned by the regulatory bodies in the member countries of the European Union (EU) in favor of incentive regulation methods in combination with regulation of the quality of supply [7], since it has become evident that application of the regulation of the rate of return raises investment costs above those that entities performing regulated activities would otherwise have to pay if they invested according to the criterion of minimal costs. Furthermore, it has become evident that in principle the regulation of the rate of return achieves the opposite effect to that which should be assured by economic regulation through an independent regulatory body. The goals of economic regulation are primarily as follows [7]:

- promoting efficiency and increasing productivity,
- assuring the appropriate financial viability of the sector,
- preventing discrimination against customers and energy entities.

The regulatory policy toward the investments by entities performing regulated activities is one of the key segments in the implementation of economic regulation. New investments, if accepted as allowed expenditures, are included in the regulatory asset base (*RAB*) through depreciation and the amount of the allowed return on assets. The regulatory body, therefore, can have a significant role in determining the justified level of investment, and thereby in the procedure for the determination of the prices for regulated activities. This is even more the case when the fact is taken into account that many legal solutions anticipate that the regulatory body will issue approval or adopt the development plans of the entities performing regulated activities.

Hrvatska je na početku uvođenja ekonomske regulacije u energetskim djelatnostima, stoga se u ovom trenutku još ne mogu analizirati učinci regulatorne politike u cijelosti kao niti pojedinih regulatornih odluka. Iako su tarifni sustavi, bez visine tarifnih stavki, doneseni u prosincu 2006. godine, koliko je poznato autorima (u vrijeme predaje ovog članka uredništvu) procedura donošenja iznosa tarifnih stavki nije još započela. Za donošenje iznosa tarifnih stavki potrebno je prije svega da energetski subjekti HEP Operator prijenosnog sustava d.o.o. (HEP OPS) i HEP Operator distribucijskog sustava d.o.o. (HEP ODS) dostave HERA-i na suglasnost prijedlog trogodišnjih planova razvoja i izgradnje, a sve temeljem Zakona o tržištu električne energije [8].

Kod razmatranja planova razvoja i izgradnje prijenosne i distribucijske mreže, nameće se pitanje koje se odnosi na dubinu nadležnosti regulatornog tijela, pa tako i HERA-e, odnosno na njegovu poziciju u odnosu na davanje suglasnosti na pojedina koncepcijska rješenja, odnosno na pojedina tehnička pitanja. Naime, temeljem Zakona o tržištu električne energije [8] HEP OPS i HEP ODS donose planove razvoja i izgradnje mreža za razdoblje od tri godine tek po ishođenoj prethodnoj suglasnosti HERA-e na svoje prijedloge planova. Doneseni planovi ujedno su i ishodište za utvrđivanje iznosa tarifa. Samim zakonskim odredbama nije razvidno definirana dubina uloge HERA-e u smislu njenih ovlasti prilikom davanja tih suglasnosti.

Budući da su iskustva u Hrvatskoj u smislu utjecaja regulatornog tijela na planove razvoja i izgradnje tek u začetku, zanimljivo je analizirati ulogu drugih regulatornih tijela u donošenju planova poslovanja, tj. razvoja i izgradnje subjekata koji obavljaju regulirane djelatnosti. Iskustva regulatornih tijela članica udruženja energetskih regulatornih tijela iz Europe (*Energy Regulators Regional Association* – ERRA) [9], u kojima je regulacija i konkurentno tržište električne energije relativno novi koncept, vrlo su različita u smislu uloge regulatornog tijela u davanju suglasnosti na planove razvoja i izgradnje. U većini slučajeva regulatorna tijela ne utvrđuju kriterije planiranja razvoja prijenosne i distribucijske mreže, niti utječu na koncepcijska i tehnička rješenja koja vrlo često proizlaze iz odluka uprave tvrtki, već se njihova uloga svodi na odobravanje poslovnih planova Operatora prijenosnih sustava (OPS) i Operatora distribucijskih sustava (ODS). Paralelno odobravanju poslovnih planova, regulatorna tijela postupno uvode i razvidne kriterije kvalitete opskrbe kako bi se izbjeglo smanjenje kvalitete opskrbe zbog smanjivanja troškova kroz primjenu regulatorne metode te da bi se ujedno postiglo planiranje razvoja mreže koje za cilj ima

The Republic of Croatia is in the initial phase of introducing economic regulation into energy activities. Therefore, at this moment it is still not possible to analyze the effects of the regulatory policy in their entirety or individual regulatory decisions. For the adoption of the amounts of tariff items, it will be necessary for the HEP Transmission System Operator – HEP TSO (HEP Operator prijesnog sustava d.o.o. – HEP OPS) and the HEP Distribution System Operator – HEP DSO (HEP Operator distribucijskog sustava – HEP ODS) as energy entities to submit their proposed three-year development and construction plans to the CERA for approval, all pursuant to the Electricity Market Act [8].

When considering the development and construction plans of transmission and distribution networks, a question arises in reference to the degree of the authority of the regulatory body, and thus of the CERA, i.e. its position in relation to issuing approval for individual conceptual solutions or individual technical questions. Pursuant to the Electricity Market Act [8], the transmission system operator and the distribution system operator only adopt plans for the development and construction of networks for a period of three years after obtaining prior approval from the CERA for their proposed plans. The adopted plans are also the basis for the determination of the amounts of tariffs. The legal provisions themselves have not transparently defined the range of the CERA's role in the sense of its authority when issuing these approvals.

Since experiences in the Republic of Croatia regarding the influence of the regulatory body on development and construction plans are only in the initial phase, it is interesting to analyze the role of other regulatory bodies in the adoption of business plans, i.e. development and construction by entities performing regulated activities. The experiences of the member regulatory bodies of the Energy Regulators Regional Association (ERRA) [9], in which regulation and a competitive electrical energy market are relatively new concepts, vary considerably in the sense of the role of the regulatory body in issuing approval for development and construction plans. In the majority of cases, the regulatory bodies neither determine the criteria for planning the development of transmission and distribution networks, nor do they influence the conceptual and technical solutions that very often ensue from the decisions of company management, but instead their role is limited to approving the business plans of the transmission system operator and the distribution system operator. Together with the approval of business plans, regulatory bodies are gradually introducing transparent criteria for the quality of supply in order to avoid lowering the quality of the supply due to reduced expenditures through the application of regulatory methods in order to

povećanje učinkovitosti, odnosno povećanje kvalitete opskrbe.

Odabirom metode regulacije priznatih troškova i regulatornog razdoblja od godinu dana unutar kojeg je moguće inicirati izmjene visine tarifnih stavki, HERA nije dala naglasak na povećanje učinkovitosti subjekata koji obavljaju regulirane djelatnosti koji je jedan od glavnih ciljeva ekonomske regulacije. Imajući u vidu iskustva drugih regulatornih tijela iz EU, nužno će u skorašnje vrijeme uslijediti izmjena regulatorne metode, a time će i HERA intenzivnije pristupiti analizi ovisnosti regulatornog pristupa i razine faktora učinkovitosti primjenjujući neku od metoda poticajne regulacije. U članku se analiziraju dva regulatorna pristupa u primjeni faktora učinkovitosti i ulozi regulatornog tijela u odobravanju investicijskih planova subjekata koji obavljaju regulirane djelatnosti poznatih pod nazivom regulatorni pristup slaganja blokova (engl. *Building Blocks Appraoch*) i regulatorni pristup ukupnog troška (engl. *Total Expenditures Approach – TOTEX Approach*). O odabranom regulatornom pristupu ovisi i način na koji regulatorno tijelo ocjenjuje učinkovitost pojedinih ulaganja i razmatra opravdanost razine predviđenih ulaganja.

## 2 PRAKSA U ČLANICAMA ENERGY REGULATORS REGIONAL ASSOCIATION

Zemljopisno gledano ERRA je udruženje regulatornih tijela iz Europe (pojedine države ujedno su i članice EU) i bivših država Sovjetskog saveza osnovano 2000. godine. Trenutačno su u udruženju punopravno učlanjena 22 regulatorna tijela uključujući i HERA-u. Na sastancima odbora ERRA-e raspravlja se i razmjenjuju se iskustva o nadležnostima regulatornih tijela, problemima i izazovima s kojima se susreću regulatorna tijela. Jedna od nadležnosti većine regulatornih tijela je i sudjelovanje u postupku donošenja razvojnih/investicijskih planova energetskih subjekata koji se bave prijenosom i distribucijom električne energije u vidu tehničkih, financijskih ili poslovnih planova. Planovi se donose kao preduvjet za utvrđivanje metodologija za izračun cijena usluga ili donošenje samih iznosa cijena usluga. Pitanja koja se nameću prilikom rasprave o ulozi regulatornih tijela u donošenju predmetnih planova su:

– koliko duboko i detaljno regulatorno tijelo treba biti uključeno u izradu i donošenje razvojnih/investicijskih planova, posebice kada se radi o strateškim dilemama ili tehničkim rješenjima,

achieve the planned development of the network with the goal of improving efficiency, i.e. improving the quality of the supply.

Through the selection of the rate of return (*RoR*) method and a regulatory period of one year within which it is possible to initiate changes in the amounts of the tariff items, the CERA did not place emphasis on increasing the efficiency of the entities performing regulated activities, which is one of the main goals of economic regulation. Bearing in mind the experiences of other regulatory bodies from the EU, changes in the regulatory method will have to follow soon, and the CERA will have to intensify its analysis of the dependence of the regulatory approach and the level of the efficiency factor, applying some incentive regulation method. In this article, two regulatory approaches are analyzed in the application of the efficiency factor and the roles of the regulatory body in the approval of the investment plans of entities performing regulated activities, known as the building block approach, and the regulatory approach known as the total expenditure approach or the *TOTEX* approach. The choice of the regulatory approach will also determine the manner in which the regulatory body will assess the performance of individual investments and analyze the justification for the level of individual investments.

## 2 PRACTICES AMONG THE MEMBERS OF THE ENERGY REGULATORS REGIONAL ASSOCIATION (ERRA)

Viewed geographically, the ERRA is an association of the energy regulatory bodies from Europe (some of the countries are also members of the EU) and the former the Soviet Union, which was established in the year 2000. Currently, there are twenty-two regulatory bodies that are full members, including the CERA. At the meetings of the ERRA committees, experiences are discussed regarding the authorities of the regulatory bodies, together with the problems and challenges encountered by the regulatory bodies. One of the authorities of the majority of the regulatory bodies is participation in the procedure for the adoption of the development/investment plans of the energy entities engaged in the transmission and distribution of electrical energy, regarding technical, financial or business plans. Plans are adopted as a prerequisite for the determination of the methodologies for the calculation of the prices for services or the adoption of the amounts of the prices of the services. Questions posed during the discussions on the role of the regulatory bodies in the adoption of these plans are as follows:

– treba li regulatorno tijelo biti ta instanca koja će utvrditi jedinični trošak pojedine opreme,
– koje sastavne dijelove mora sadržavati svaki razvojni/investicijski plan.

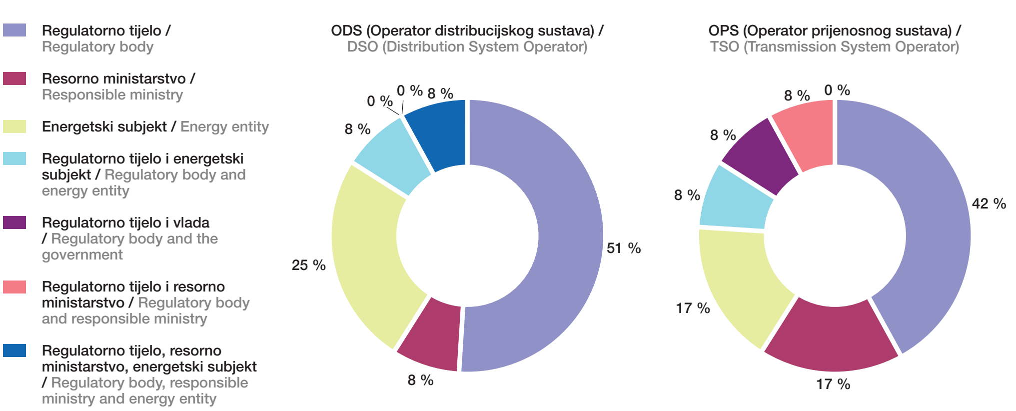
Na ova pitanja i dileme ERRA-in Odbor za tarife i cijene pokušao je u 2005. godini odgovoriti kroz analizu iskustava država članica [9]. Međutim, provedena analiza je pokazala da se uloga regulatornog tijela u donošenju razvojnih/investicijskih planova značajno razlikuje ovisno o zakonskim rješenjima, nadležnostima regulatornih tijela te stručnoj, tehničkoj i financijskoj osposobljenosti regulatornih tijela.

Upitnik koji je tom prilikom pripremljen, analiziran i prezentiran sadrži 33 pitanja. Svoje odgovore na pitanja iz Upitnika dala su regulatorna tijela iz 12 država (Armenija, Bosna i Hercegovina, Bugarska, Hrvatska, Estonija, Gruzija, Latvija, Litva, Makedonija, Poljska, Rumunjska i Ukrajina). U državama koje su odgovorile na Upitnik broj OPS-ova uglavnom je jedan, dok se broj ODS-ova kreće između 1 i više od 200 (Poljska). U većini država regulatorno tijelo daje suglasnost na razvojne/investicijske planove OPS-a i ODS-a (slika 1). Međutim, postoje i rješenja u kojima regulatorno tijelo nije uključeno u proces donošenja planova, već je to npr. u potpunosti u nadležnosti energetskih subjekata. Razdoblje na koje se donose planovi kreće se od jedne do deset godina, kako za OPS tako i za ODS.

– how deep and thorough should a regulatory body's involvement be in the preparation and adoption of development/investment plans, especially regarding strategic dilemmas or technical solutions?
– should the regulatory body be the one to define the unit costs of individual types of equipment?
– what are the integral parts that every development/investment plan should have?

In 2005, the ERRA Tariff/Pricing Committee attempted to answer these questions and dilemmas through analysis of the experiences of the member countries [9]. However, the analysis performed demonstrated that the roles of the regulatory bodies in the adoption of development/investment plans vary significantly, depending upon the legal solutions, the authorities of the regulatory bodies and the professional, technical and financial abilities of the regulatory bodies.

The questionnaire that was prepared, analyzed and presented on this occasion has thirty-three questions. The regulatory bodies from twelve countries (Armenia, Bosnia and Herzegovina, Bulgaria, Croatia, Estonia, Georgia, Latvia, Lithuania, Macedonia, Poland, Rumania and the Ukraine) answered the questions on the questionnaire. In the countries that responded to the questionnaire, the number of TSO (transmission system operators) is generally one, while the number of DSO (distribution system operators) ranges between one and over two hundred (Poland). In the majority of the countries, the regulatory body issues approval for the development/investment plans of the transmission system operators and distribution system operators (Figure 1). However, there are also solutions in which the regulatory body is not included in the process of the adoption of plans but instead, for example, the energy entities have full authorization for this. The periods for which plans are adopted range from one to ten years, for both transmission system operators and distribution system operators.




**Slika 1**
Raspodjela nadležnosti davanja suglasnosti na planove razvoja/investicija ODS-a i OPS-a u članicama ERRA-e (analiza je provedena za 12 država)
**Figure 1**
Distribution of authority for issuing approval for the development/investment plans of distribution system operators and transmission system operators among the members of ERRA. (Analysis was performed for twelve countries)

Pitanja koja su zanimljiva za ulogu regulatornog tijela u donošenju planova posebice se odnose na dubinu regulatornog utjecaja u području:

- tehničkih rješenja, npr. zamjena elektro-mehaničkih digitalnim mjernim uređajima,
- koncepcijskih dilema u razvoju visokonaponske (VN) i srednjonaponske (SN) mreže, kao što je npr. interpolacija SN/SN trafostanica,
- troška građevinskih radova,
- utvrđivanja jediničnih troškova opreme.

Prva dva područja u načelu su u većini država u nadležnosti energetskih subjekata i stvar su odluke OPS-a, odnosno ODS-a. Utvrđivanje troškova za druga dva navedena područja proizlazi iz javnih nabava. Isto tako, kada se analizira tko je nadležan za utvrđivanje kriterija za planiranje prijenosne i distribucijske mreže, proizlazi da su to prvenstveno energetski subjekti, a ne regulatorna tijela (slika 2).

Postavlja se pitanje koja je onda stvarna uloga regulatornih tijela u donošenju planova razvoja/investicija OPS-a/ODS-a, odnosno kakav utjecaj može imati regulatorno tijelo na dinamiku i visinu investicija, kao i na koncepcijska rješenja. Budući da je većina analiziranih regulatornih tijela u načelu tek u početku primjene regulatorne prakse te uspostavljanja kompetentnog i stručno osposobljenog regulatornog tijela, u većini slučajeva regulatorna uloga se svodi na analizu i nadzor financijskih i računovodstvenih izvješća, a ne na utvrđivanje kriterija za tehnička rješenja i odobravanje opravdane visine pojedinih investicija. Kao ilustrativni primjer financijskog, odnosno poslovnog, nadzora može se navesti praksa u pojedinim državama članicama ERRA-e koje su odgovorile na pitanje iz upitnika koje se odnosi na financijske i poslovne kriterije utvrđene za regulatorni nadzor energetskih subjekata.

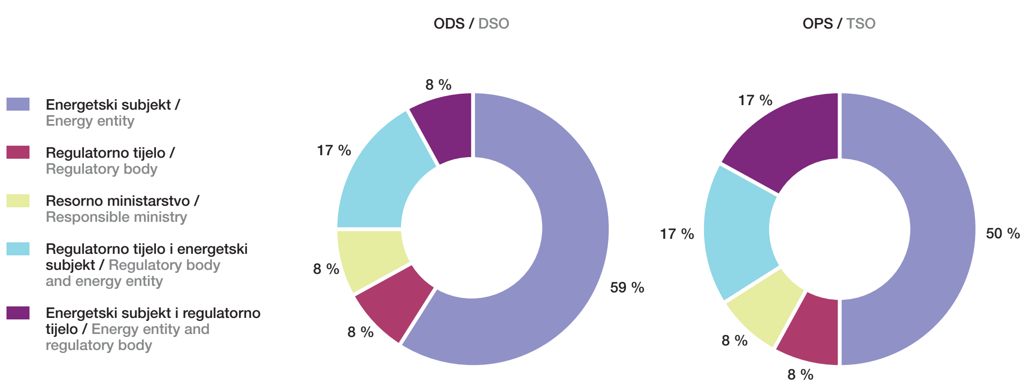
Questions of interest regarding the role of the regulatory body in the adoption of plans particularly refer to the extent of regulatory influence in the following areas:

- technical solutions, e.g. the replacement of electromechanical metering devices with digital ones,
- conceptual dilemmas in the development of high voltage and medium voltage networks, such as, for example, the interpolation of MV/MV substations,
- costs of construction work, and
- the determination of the unit costs of equipment.

In the majority of the countries, the first two areas are in principle under the authority of the energy entities and matters for decision by the transmission system operator or the distribution system operator. The definition of costs for the other two areas mentioned comes from public procurements. Similarly, it is primarily the energy entities and not the regulatory bodies which are authorized to define the criteria for the planning of transmission and distribution networks (Figure 2).

Therefore, the question is posed concerning the actual roles of the regulatory bodies in the adoption of the development/investment plans of transmission system operators and distribution system operators, i.e. what influence can a regulatory body have on the dynamics and amount of investment, as well as on the conceptual solution. Since the majority of the analyzed regulatory bodies in principle are only beginning to apply regulatory practices in the establishment of competent and professionally qualified bodies, in the majority of cases the regulatory role is limited to the analysis and audit of financial and accounting reports, and not the determination of the criteria for the technical solutions and the approval of the justified amounts of individual investments. An illustrative example of financial or operational supervision is the practice in some member countries of the ERRA which responded to the questions on the questionnaire that refer to the financial and operational criteria established for the regulatory supervision of energy entities.

**Slika 2**
Raspodjela nadležnosti za utvrđivanje kriterija za planiranje prijenosne i distribucijske mreže u članicama ERRA-e (analiza je provedena za 12 država)
**Figure 2**
The distribution of authority for the determination of criteria for the planning of transmission and distribution networks among member countries of the ERRA (analysis of 12 countries)



U Bugarskoj se financijski nadzor provodi na temelju odabranih financijskih pokazatelja koji su utvrđeni kao pokazatelji od važnosti za regulatorni nadzor. Analiza ovih pokazatelja trebala bi odgovoriti na pitanje primjenjuju li energetski subjekti mjere utvrđene od strane regulatornog tijela koje za cilj imaju povećanje ekonomske učinkovitosti proizašle iz primjene poticajne regulacije. U Latviji tarifna metodologija utvrđuje način na koji se dostavlja prijedlog tarifa, odnosno utvrđuje set potrebnih podataka koje je potrebno dostaviti regulatornom tijelu. U Ukrajini nadzor poslovnih planova provodi se kroz računovodstveni nadzor i izvješća za potrebe regulatornog tijela. Poslovni, odnosno investicijski planovi između ostalog moraju sadržavati iznos godišnjeg budžeta, izvor financiranja te detaljnu elaboraciju troškova. Za ukrajinsko regulatorno tijelo potrebno je naglasiti da već dugi niz godina primjenjuje razne vrste metoda ravnanja prema mjerilu (engl. *benchmarking*) za koje je podatak o troškovima za pojedinačne investicije više nego dobrodošao.

Odgovori na Upitnik pokazali su da u većini država regulatorno tijelo provodi nadzor nad realizacijom predviđenih investicija tijekom postupka utvrđivanja tarifa za novo regulatorno razdoblje. Ono što je bitno kod utvrđivanja cijena usluga i uključivanja pojedinih troškova u razinu prihoda energetskog subjekta odobrenog od strane regulatornog tijela je realizacija investicija iz investicijskog ciklusa. Naime, ukoliko je pojedina investicija odobrena i uključena u investicijske planove, te su za istu alocirana potrebna sredstva u regulatornom razdoblju, tu istu investiciju ne može se uključiti u regulirani trošak u novom regulatornom razdoblju. Proizlazi da je nadzor regulatornog tijela vrlo bitan u segmentu nadzora nad realizacijom investicijskih planova subjekata koji obavljaju regulirane djelatnosti.

Ukoliko energetski subjekt ne realizira predviđeni investicijski ciklus, u pojedinim državama (Armenija, Latvija, Litva, Poljska, Ukrajina), u sljedećem regulatornom razdoblju dolazi do smanjenja iznosa reguliranih tarifnih stavki. No, moguća su i drastičnija rješenja, kao npr. u Armeniji, gdje regulatorno tijelo osim smanjenja iznosa tarifnih stavki može izreći upozorenje ili oduzeti dozvolu za obavljanje energetske djelatnosti. Međutim, ukoliko se radi o OPS-u, postavlja se pitanje tko će obavljati djelatnost ukoliko se oduzme dozvola. Nadalje, kao sankcija za neispunjavanje investicijskog ciklusa, moguće su i novčane kazne, npr. u Ukrajini do 16 000 američkih dolara. I u hrvatskom zakonu [8] predviđena je novčana kazna za energetski subjekt u iznosu do 50 000 kuna ukoliko ne izrađuje planove razvoja i izgradnje, odnosno ukoliko ih ne

In Bulgaria, financial supervision is performed on the basis of selected financial indices that are determined as indices of importance for regulatory supervision. Analysis of these indices should answer the question of whether energy entities apply the measures determined by the regulatory body with the goal of achieving increased economic performance through the application of incentive regulations. In Latvia, the tariff methodology determines the manner in which a proposed tariff should be submitted, i.e. determines the set of necessary data that must be submitted to the regulatory body. In the Ukraine, supervision of business plans is performed through accounting supervision and reports for the purposes of the regulatory body. Business or investment plans, among other things, must contain the amount of the annual budget, the source of financing and a detailed elaboration of costs. For the Ukrainian regulatory body, it is necessary to emphasize that various types of methods based upon benchmarking have been applied for many years, for which data on the costs for individual investments are more than welcome.

Responses to the questionnaire showed that in the majority of the countries, the regulatory body supervises the implementation of planned investment through the procedure of determining the tariffs for the new regulatory period. What is important in the determination of the prices for services and the inclusion of individual costs in the level of the revenues of the energy entity approved by the regulatory body is the implementation of investment from the investment cycle. Insofar as an individual investment is approved and included in investment plans, and the necessary assets are allocated for it in the regulatory period, this same investment cannot be included in the regulated expenditures in the new regulatory period. Therefore, it follows that supervision by the regulatory body is very important in the segment of supervising the implementation of the investment plans of a entities performing regulated activities.

If an energy entity does not implement a planned investment cycle, in some countries (Armenia, Latvia, Lithuania, Poland and the Ukraine) there is a reduction in the amounts of the regulated tariff items in the subsequent regulatory period. However, even more drastic solutions are possible, such as, for example, in Armenia where the regulatory body, in addition to reducing the amounts of the tariff items, can also issue a warning or revoke the license for performing energy operations. However, when this concerns a transmission system operator, the question is asked who will perform the activity if the license is revoked. Furthermore, monetary fines can be imposed as penalties for not fulfilling an investment cycle such as, for example, in the Ukraine of up to USD 16 000.

izrađuje temeljem Strategije energetskog razvitka i Programa provedbe Strategije.

Radi lakše provedbe postupka davanja suglasnosti na planove od strane regulatornog tijela i kasnijeg nadzora nad provedbom planova u pojedinim državama (Bugarska i Ukrajina) struktura sadržaja planova je predefinirana. U Litvi razvojni/investicijski planovi moraju zadovoljiti nužan minimum sadržaja planova, a to je:

– obrazac potpisan od strane odgovorne osobe sa svim potrebnim podacima djelatnika (imena, telefon, e-mail adresa) koji su sudjelovali u izradi planova,
– popis planiranih investicija koje moraju biti u skladu sa strategijom razvoja i dugoročnim planovima razvoja mreža, uključujući iznos potrebnih financijskih sredstava, izvore financiranja, terminski plan i slično,
– pisano obrazloženje u vidu investicijskog plana za razdoblje od tri godine iz kojeg je vidljiv učinak pojedine investicije, kako u tehničkom tako i ekonomskom, socijalnom i ekološkom pogledu. Isto tako potrebno je navesti utjecaj pojedine investicije na cijenu, kvalitetu usluge i sl. U odgovoru na pitanje iz Upitnika nije navedeno do koje naponske razine ili koje visine investicije je potrebno pisati ovako detaljna pojašnjenja razloga za pojedinu investiciju,
– energetski subjekt treba osigurati i druge podatke ili dokumente ukoliko regulatorno tijelo ustanovi da su potrebni za mjerodavan stav regulatornog tijela.

U dijelu Upitnika koji se odnosi na povezanost planova i regulatornih parametara, kao što je to stopa povrata na kapital, većina regulatornih tijela odgovorila je da institucija koja odobrava planove ne treba predefinirati pojedine regulatorne parametre kojima bi se služili u analizi planova. Izuzetak je Bugarska u kojoj regulatorno tijelo može dati instrukcije, u smislu davanja informacije o aproksimativnom iznosu pojedinih regulatornih parametara, kao što je npr. stopa povrata na kapital kojom se energetski subjekt može koristiti prilikom izrade planova razvoja/investicija.

Under Croatian law [8], a monetary fine for an energy entity in the amount of up to 50 000 kunas is stipulated if development and construction plans are not prepared, i.e. if they are not prepared according to the Energy Development Strategy and the Program for the Implementation of the Strategy.

To facilitate implementation, the procedures for issuing approval for plans by the regulatory body and subsequent supervision of the implementation of plans in some countries (Bulgaria and the Ukraine), the structure of the content of the plans are predefined. In Lithuania, development/investment plans must include the necessary minimum contents of the plans, as follows:

– a form should be signed by the responsible persons, with all the necessary data on the employees (names, telephone numbers and e-mail addresses) who participated in the preparation of the plans,
– there should be a list of the planned investments, which must be pursuant to the development strategy and long-range plans for the development of the network, including the amount of the necessary financial assets, the sources of financing, schedule etc.,
– there should be a written explanation regarding the investment plan for the period of three years, from which the impact of individual investments is visible, in the economic, social and ecological aspects. Furthermore, it is necessary to state the impact of individual investments on price, quality of service etc. The responses to a question from the questionnaire do not indicate the voltage level or the level of investment that require a detailed written explanation of the reasons for an individual investment,
– the energy entity should also provide other data or documents if the regulatory body deems that they are necessary in order for it to determine its position.

In the part of the questionnaire that refers to the connection between plans and regulatory parameters, such as the rate of return on capital, the majority of the regulatory bodies answered that the institution that approves plans does not have to predefine the individual regulatory parameters that it would use in the analysis of the plans, with the exception of Bulgaria in which the regulatory body can provide instructions in the sense of furnishing information on the approximate amounts of regulatory parameters, such as, for example, the rate of return on capital that an energy entity can use in preparing development/investment plans.

Zaključak koji se može izvući iz odgovora na pitanja iz Upitnika je da regulatorna tijela ukoliko imaju u nadležnosti davanje suglasnosti na planove razvoja/investicija OPS-a i ODS-a, u načelu suglasnost daju na mogućnost realizacije predviđenih investicija u financijskom pogledu te na rezultate koji se postižu predviđenim investicijama. Pod rezultatima smatra se povećanje učinkovitosti subjekata koji obavljaju regulirane djelatnosti ili povećanje razine kvalitete opskrbe. Ono što je potrebno naglasiti kao zaključak razmatranja odgovora na Upitnik je da se analizirana regulatorna tijela ne miješaju u koncepcijska tehnička rješenja u planovima razvoja i izgradnje mreža.

Da bi se moglo govoriti o povećanju učinkovitosti koja je rezultat primjene poticajne regulacije i o utjecaju razine odobrenih investicija na razinu dozvoljenog prihoda reguliranog subjekta, potrebno je dati prikaz, odnosno analizu, mogućih regulatornih politika u primjeni poticajne regulacije. Pri tome važnu ulogu ima osnovica na koju se primjenjuje faktor učinkovitosti te dinamika realizacije predviđenih investicija i amortizacijska politika.

## 3 UTJECAJ REGULATORNE POLITIKE NA DOZVOLJENI PRIHOD

Do sada je bilo riječi o nadležnosti regulatornog tijela u donošenju planova razvoja/investicija, a da se pri tome nije analizirala regulatorna politika u kojoj važnu ulogu ima cilj koji se želi postići pojedinim investicijskim ciklusom te razina odobrenih investicija koje se uključuju u regulirane troškove. Kontekst regulatorne politike koji se razmatra u ovom članku prvenstveno se odnosi na poticajnu regulaciju čije su značajke u detalje razmatrane u literaturi pod [6], a za koju je, ukoliko se radi o metodi regulacije maksimalnog prihoda, karakteristična sljedeća formula:

The conclusion that can be drawn from the responses to the questions on the questionnaire is that the regulatory bodies, insofar as they have the authority to approve the development/investment plans of the transmission system operator and the distribution system operator, in principle issue approval based upon the feasibility of the implementation of the planned investments in the financial aspect and based upon the results to be achieved by the planned investments. Results include the increased efficiency of the entities performing regulated activities or improved quality of the supply. It is necessary to emphasize that a conclusion drawn from a review of the responses to the questionnaire is that the analyzed regulatory bodies do not interfere in the conceptual technical solutions of the network development and investment plans.

In order to speak about the increased efficiency resulting from the application of incentive regulations and the impact of the level of approved investments on the level of the allowed revenue of entities performing regulated activities, it is necessary to provide a presentation, i.e. an analysis, of the potential regulatory policies in the application of incentive regulations. Important roles are played by the base upon which the efficiency factor is applied, the dynamics of the implementation of planned investments and the depreciation policy.

## 3 THE IMPACT OF REGULATORY POLICIES ON ALLOWED REVENUE

Thus far, the authority of the regulatory body in the adoption of development/investment plans has been discussed without analyzing the regulatory policies, in which the desired goal to be achieved by an individual investment cycle and the level of approved investments included under regulated expenditures have important roles. The context of the regulatory policies that are discussed in this article primarily refers to incentive regulation, the characteristics of which are discussed in detail in the literature [6], and for which, insofar as they concern methods for the regulation of maximum revenue, are characterized by the following formula:

$$P_{\max t} = (1 + CPI_t - X_t) \cdot P_{\max(t-1)} - KP_t$$

$$R_{\max t} = (1 + CPI_t - X_t) \cdot R_{\max(t-1)} - KP_t \qquad (1)$$

gdje je:

$P_{\max t}$ – gornja granica dozvoljenog prihoda u godini $t$,

where:

$R_{\max t}$ – the upper limit of revenue, i.e. revenue-cap, in year $t$,

$P_{max\,(t-1)}$ – gornja granica dozvoljenog prihoda u godini $t$ -1,
$CPI_t$ – indeks potrošačkih cijena u godini $t$,
$X_t$ – faktor učinkovitosti u godini $t$,
$KP_t$ – faktor korekcije u godini $t$.

Mehanizam poticajne regulacije prije svega nastoji kroz poticaje ($X$-faktor) povećati učinkovitost energetskih subjekta. Pri tome vrijedi pretpostavka da je energetski subjekt u stanju kontrolirati razinu svojih troškova. Za troškove za koje se smatra da ih energetski subjekt ne može kontrolirati, odnosno da su izvan kontrole subjekta, kao što su to npr. porezi, naknada za regulaciju, troškovi koje je prouzročila viša sila i sl., ne može se očekivati povećanje učinkovitosti subjekta na račun njihovog smanjenja. Stoga se poticaji primjenjuju na razinu kontroliranih troškova, dok se nekontrolirani troškovi smatraju prolaznim i u cjelokupnom iznosu se prebacuju na kupca. Detaljna elaboracija granice između kontroliranih i nekontroliranih troškova zahtijeva dublje analize od strane regulatornog tijela. Kao primjer troškova koji se mogu svesti u sferu kontroliranih i nekontroliranih troškova su troškovi tehničkih gubitaka u mreži. Ukoliko regulatorno tijelo smatra da su gubici u potpunosti nekontrolirani trošak, prihvaća njihovu razinu, odnosno njihov trošak, u iznosu koji prijavljuje energetski subjekt. U tom slučaju energetski subjekt neće imati nikakav poticaj da ih smanji, bilo u vidu troška bilo u vidu fizičkih gubitaka izraženih u kWh. Međutim, ukoliko ih regulatorno tijelo smatra kontroliranim troškom, nastojat će ih kroz regulatornu politiku svesti u granice koje se sa stajališta regulatornog tijela čine opravdanima.

Kada se radi o kontroliranim troškovima, regulatorna politika razlikuje dvije grupe troškova:

– operativne troškove (engl. *Operating Expanditures – OPEX*), troškovi koje je moguće kontrolirati u kratkoročnom razdoblju i
– kapitalne troškove (engl. *Capital Expanditures – CAPEX*), troškove koje je moguće kontrolirati u dugoročnom razdoblju.

U *OPEX* se ubrajaju troškovi osoblja, materijalni troškovi, troškovi održavanja, ostali troškovi poslovanja i sl. Troškovi koje je moguće prilagođavati u relativno kratkom roku. S druge pak strane, *CAPEX* se u kratkoročnom razdoblju može promatrati kao fiksni trošak budući da se i prvenstveno radi o troškovima koji se vežu uz investicije u razvoj mreža i poboljšanje kvalitete opskrbe. *CAPEX* je moguće podijeliti u dvije grupe – amortizaciju i povrat sredstava koji se definira kao godišnja stopa povrata primijenjena na neamortizirani dio ulaganja. Povrat sredstava u načelu utvrđuje regulator-

$R_{max\,(t-1)}$ – the upper limit of revenue, i.e. revenue-cap, in year $t$ -1,
$CPI_t$ – the consumer price index in year $t$,
$X_t$ – the efficiency factor in year $t$,
$KP_t$ – the correction factor in year $t$.

The mechanism of incentive regulation primarily attempts to increase the efficiency of energy entities through incentives (the $X$-factor). It is presumed that an energy entity is in a position to control the level of its expenditures. For expenditures presumed to be non-controllable by an energy entity, i.e. that are out of the control of the entity, such as, for example, taxes, regulation charges, expenditures due to force majeure etc., it is not possible to expect that the entity will achieve increased efficiency by reducing them. Therefore, incentives are applied at the level of controllable costs, while non-controllable costs are considered to be transitory and are transferred in their entirety to the customers. A detailed elaboration of the boundary between controllable and non-controllable expenditures requires in-depth analysis by the regulatory body. An example of expenditures that can be classified within the spheres of both controllable and non-controllable expenditures are the costs of technical losses in the network. Insofar as the regulatory body considers the losses to be entirely non-controllable expenditures, it accepts their level, i.e. their cost, in the amount that the energy entity reports. In this case, the energy entity will not have any incentive to reduce them, whether in the aspect of expenditures or the aspect of physical losses expressed in kWh. However, insofar as the regulatory body considers them to be controllable expenditures, it will attempt to lower them through regulatory policy to within the limits considered justified from the standpoint of the regulatory body.

Concerning controllable expenditures, regulatory policy differentiates between two groups of expenditures:

– Operating expenditure – *OPEX*, expenditure that can be controlled within a short-term period
– Capital expenditure – *CAPEX*, expenditure that can be controlled within a long-term period.

Under *OPEX* are included personnel costs, material costs, maintenance costs, other operating costs etc. These are expenditures that can be adjusted within a relatively short period. On the other hand, *CAPEX* can be considered as fixed expenditures within a short-term period, primarily concerning expenditures in connection with investment in network development and improvement in the quality of the supply. *CAPEX* can be divided into two groups – depreciation and return on assets, defined as the annual rate of return applied to the non-depreciated portion of investment. In principle, the return

no tijelo na osnovi troška kapitala subjekata koji obavljaju regulirane djelatnosti [7].

Imajući u vidu da regulatorno tijelo u načelu može regulirati dvije kategorije troškova, moguće je definirati dva pristupa u regulaciji. Prvo, regulatorno tijelo može primjenjujući pojedinu metodu poticajne regulacije zasebno razmatrati *OPEX* i *CAPEX*. Ovakav pristup poznat je pod nazivom regulatorni pristup slaganja blokova, budući da se sastoji od dvije komponente, odnosno bloka, za koje regulatorno tijelo pojedinačno utvrđuje opravdanu razinu.

Drugi pristup se odnosi na regulatornu politiku u kojoj regulatorno tijelo *OPEX* i *CAPEX* razmatra kao integrirani trošak na koji se sumarno primjenjuje odabrana metoda poticajne regulacije. Ovakav pristup poznat je pod nazivom regulatorni pristup ukupnog troška. *TOTEX* označava sumu *OPEX*-a i *CAPEX*-a. U nastavku razmatra se svaki od pristupa pojedinačno.

### 3.1 Regulatorni pristup slaganja blokova

U regulatornom pristupu slaganja blokova regulatorno tijelo mora odvojeno analizirati učinkovitu, odnosno opravdanu razinu, *OPEX*-a i *CAPEX* -a. Pri ocjenjivanju razine učinkovitosti i opravdanosti *OPEX*-a čest je slučaj da regulatorna tijela koriste razne metode ravnanja prema mjerilu [7]. Međutim, utvrđivanje faktora učinkovitosti $X$ u formuli za poticajnu regulaciju (1) zahtijeva puno složeniji postupak, uključujući i diskrecijske odluke regulatornih tijela, od direktnog uvrštavanja rezultata dobivenih primjenom neke od poznatih metoda ravnanja prema mjerilu.

Dozvoljena razina *CAPEX*-a utvrđuje se na osnovi investicijskih planova energetskih subjekata predviđenih za sljedeće regulatorno razdoblje. Na osnovi predloženih investicija, regulatorno tijelo procjenjuje koje investicije uključiti u regulatornu osnovicu sredstava. Investicije koje su uključene u regulatornu osnovicu sredstava bit će u potpunosti uključene u trošak amortizacije te će se na neamortizirani dio primijeniti stopa povrata na uloženi kapital.

Čest je slučaj da se predviđena razina investicija promatra kao trošak koji se prihvaća na razini prijedloga energetskih subjekata. Ukoliko regulatorno tijelo u potpunosti prizna predložene investicije, kod energetskog subjekta se stvara poticaj da prikazuje što veću razinu budućih investicija ne vodeći se opravdanim razlozima kao što su smanjenje gubitaka u mreži ili postizanje optimalne, odnosno propisane razine kvalitete opskrbe. Pri tome energetski subjekt ima u vidu da će se veća

on assets is determined by the regulatory body on the basis of the capital expenditures of the entities performing regulated activities [7].

Bearing in mind that the regulatory body can in principle regulate the two categories of expenditures, it is possible to define two approaches to regulation. First, when the regulatory body applies an individual incentive regulation method, it can consider *OPEX* and *CAPEX* separately. Such an approach is known as the building block approach, since it consists of two components, i.e. blocks, for which the regulatory body determines the justifiable levels individually.

The second approach refers to the regulatory policy in which the regulatory body considers *OPEX* and *CAPEX* as an integrated expenditure, to which the selected incentive regulation method is summarily applied. Such an approach is known as the total expenditure, *TOTEX*, regulatory approach. *TOTEX* represents the sum of *OPEX* and *CAPEX*. Each approach will be discussed separately.

### 3.1 The building block regulatory approach

In the building block regulatory approach, the regulatory body must analyze the efficiency or justified level of *OPEX* and *CAPEX* separately. In assessing the efficiency and justified level of *OPEX*, a regulatory body frequently employs various benchmarking methods [7]. However, the determination of the efficiency factor $X$ in the formula for incentive regulation (1) requires a far more complex procedure, including discretional decisions by the regulatory bodies, such as the direct classification of the results obtained from the application of some of the well-known benchmarking methods.

The allowed level of *CAPEX* is determined on the basis of the investment plans of energy entities for the subsequent regulatory period. On the basis of the proposed investments, the regulatory body assesses which investments to include in the regulatory asset base (*RAB*). Investments that are included in the regulatory asset base will be fully included in the depreciation cost, and the return rate on invested capital will be applied to the non-depreciated part.

It is frequently the case that the investment level is considered as an expenditure which is accepted at the level of the proposals by the energy entities. Insofar as the regulatory body recognizes the proposed investments in full, incentive is created for the energy entity to show the highest possible level of future investments, whether or not they are based upon justified reasons such as reducing losses in the network or achieving the optimal, i.e.

razina investicija uključiti u regulatornu osnovicu sredstava, a time će biti i veći povrat sredstava, što će se u konačnici odraziti i na profite. Energetskom subjektu bit će u interesu prikazati što veće investicije u budućem regulatornom razdoblju. Povodeći se tim načelom postoji i mogućnost da pojedine *OPEX* troškove energetski subjekt prikaže kao *CAPEX*. Na taj način pojedini *OPEX* troškovi nisu uključeni u poticajni mehanizam povećanja učinkovitosti na razini *OPEX* troškova. Time će se postići privid manjih *OPEX* troškova, odnosno postizanje veće učinkovitosti energetskog subjekta u sferi *OPEX* troškova. Strateška alokacija *OPEX*-a pod *CAPEX*, odnosno povećanje regulatorne osnovice sredstava na taj način, uočena je već u nekim slučajevima regulatornog nadzora posebice u Velikoj Britaniji [10].

Postavlja se pitanje na koji način regulatorno tijelo može reagirati ukoliko se tijekom regulatornog razdoblja ne realiziraju sve predviđene investicije odobrene od strane regulatornog tijela. Ukoliko se pokaže da nisu realizirane sve predviđene investicije, regulatorno tijelo može u sljedećem regulatornom razdoblju utvrditi niže cijene usluga, odnosno može ne dozvoliti ponovno uključivanje nerealiziranih investicija u regulatornu osnovicu sredstava. Međutim, da bi regulatorni pristup bio dosljedan i razvidan za obje strane, regulatorno tijelo i energetski subjekt, regulatorno tijelo može utvrditi donju i gornju granicu za realizaciju investicija iz plana poslovanja i razvoja. Prekomjerne investicije neće biti uopće uključene u regulatornu osnovicu sredstava ili će biti uključene samo djelomično. Ono što predstavlja problem u takvom regulatornom pristupu je da energetski subjekt nema poticaja za povećanje učinkovitosti u segmentu *CAPEX* -a. Naime, ukoliko se ostvari manji *CAPEX* od predviđenog, regulatorno tijelo će u načelu u budućem regulatornom razdoblju kao osnovicu za izračun imati manji *CAPEX*, bez obzira da li se radi o uštedama na račun podinvestiranosti (manjeg razmjera investicija od odobrenih) ili o povećanju produktivnosti energetskog subjekta. Energetski subjekt ne ostvaruje nikakve financijske koristi od povećanja učinkovitosti u segmentu *CAPEX* -a.

the stipulated, level of supply quality. The energy entity must bear in mind that a higher level of investment will be included in the regulatory asset base and, therefore, there will be a greater return on assets, which will ultimately reflect upon profits. Consequently, it is in the interest of the energy entity to show the maximum investments in the future regulatory period. Consequently, there is also the possibility that an individual *OPEX* by an energy entity is shown as a *CAPEX*. In this manner, individual operating expenditures are not included in the incentive mechanism for increasing efficiency at the level of *OPEX*. In this manner, apparently lower operating expenditures will be achieved, i.e. greater efficiency of the energy entity in the sphere of *OPEX*. The strategic allocation of operating expenditures under capital expenditures, i.e. increasing the regulatory asset base in this manner, has already been noted in some cases of regulatory supervision, especially in Great Britain [10].

The question is posed regarding how a regulatory body can react if all the planned investments that it has approved have not been made during a regulatory period. Insofar as all the planned investments have not been implemented, during the subsequent regulatory period the regulatory body can set lower prices for services or can prohibit non-implemented investments from being included in the regulatory asset base again. However, in order for the regulatory procedure to be consistent and transparent for both sides, the regulatory body and the energy entity, the regulatory body can set lower and upper limits for the implementation of investment from the business and development plans. Excessive investment will not be included in the regulatory asset base or will be included only in part. What represents a problem in such a regulatory approach is that an energy entity does not have any incentive to increase efficiency in the *CAPEX* segment. If there is lower *CAPEX* than anticipated, in principle the regulatory body will have lower *CAPEX* as a base for calculation in the subsequent regulatory period, regardless of whether this concerns savings at the expense of under investment (lower investment than approved) or increased productivity by the energy entity. Therefore, the energy entity does not derive any financial benefits from increasing efficiency in the *CAPEX* segment.

Tablica 1 – Pojednostavljen primjer izračuna dozvoljenog prihoda primjenom regulatornog pristupa slaganja blokova
Table 1 – Simplified example of the calculation of the allowed revenue through the application of the building block regulatory approach

| | |
|---|---|
| **Regulatorni parametri / Regulatory parameters** | |
| *OPEX* – faktor učinkovitosti / *OPEX* – efficiency factor | 90 % |
| Godišnje smanjenje *OPEX*-a / Annual reduction in *OPEX* | 2,60 % |
| Razdoblje amortizacije (godina) / Depreciation period (years) | 20 |
| Stopa povrata / Rate of return | 7 % |

| | Godine / Year | | | | |
|---|---|---|---|---|---|
| | 0. | 1. | 2. | 3. | 4. |
| | ($10^6$ HRK) | ($10^6$ HRK) | ($10^6$ HRK) | ($10^6$ HRK) | ($10^6$ HRK) |
| **Odobrene investicije / Authorized investments** | | 1 000,00 | 1 200,00 | 1 000,00 | 1 400,00 |
| | | | | | |
| Odobrena amortizacija / Authorized depreciation | | | | | |
| – od prethodnih investicija / from previous investments | | 700,00 | 700,00 | 700,00 | 700,00 |
| – od investicija iz 1. godine / from investments from the 1st year | | 50,00 | 50,00 | 50,00 | 50,00 |
| – od investicija iz 2. godine / from investments from the 2nd year | | | 60,00 | 60,00 | 60,00 |
| – od investicija iz 3. godine / from investments from the 3rd year | | | | 50,00 | 50,00 |
| – od investicija iz 4. godine / from investments from the 4th year | | | | | 70,00 |
| **– Ukupno odobrena amortizacija / Total authorized depreciation** | | 750,00 | 810,00 | 860,00 | 930,00 |
| | | | | | |
| **Izračun regulatorne osnovice (*ROS*) / Calculation of the regulatory asset base (*RBA*)** | | | | | |
| – početni *ROS* / initial *RBA* | | 3 000,00 | 3 250,00 | 3 640,00 | 3 780,00 |
| – plus: nove investicije / plus: new investments | | 1 000,00 | 1 200,00 | 1 000,00 | 1 400,00 |
| – minus: amortizacija / minus: depreciation | | 750,00 | 810,00 | 860,00 | 930,00 |
| – konačni *ROS* / final *RBA* | 3 000,00 | 3 250,00 | 3 640,00 | 3 780,00 | 4 250,00 |
| **– prosječni *ROS* / mean *RBA*** | | 3 125,00 | 3 445,00 | 3 710,00 | 4 015,00 |
| | | | | | |
| **Izračun ukupnog dopuštenog prihoda / Calculation of total authorized revenue** | | | | | |
| – *OPEX* / *OPEX* | 2 400,00 | 2 337,60 | 2 276,82 | 2 217,63 | 2 159,97 |
| – amortizacija / depreciation | 700,00 | 750,00 | 810,00 | 860,00 | 930,00 |
| – povrat sredstava (stopa povrata **ROS*) / return on assets (return rate **RBA*) | 210,00 | 218,75 | 241,15 | 259,70 | 281,05 |
| **– dozvoljeni prihod / allowed revenue** | 3 310,00 | 3 306,35 | 3 327,97 | 3 337,33 | 3 371,02 |

Nadalje, problem koji se javlja prilikom uspostave ciljane razine investicija je da ta razina mora odražavati učinkovitu razinu svake pojedine investicije koja se uključuje u regulatornu osnovicu sredstava. Da bi ovakav pristup bio moguć, regulatorno tijelo mora imati dovoljnu količinu informacija kao i dovoljan broj stručno osposobljenih ljudi, što se u praksi često pokazalo neostvarivim. Problem se dodatno komplicira budući da je primjena neke od metoda ravnanja prema mjerilu na *CAPEX* -a poprilično složen i težak postupak za primjenu, stoga ga regulatorna tijela izbjegavaju. Polazište za definiranje investicijskog plana

Furthermore, a problem that arises when establishing a target level of investment is that it must reflect the level of the performance of each individual investment that is included in the regulatory asset base. In order for this approach to work, the regulatory body must have a sufficient amount of information as well as a sufficient number of qualified personnel, which in practice is often unfeasible. The problem is additionally complicated because the application of some benchmarks to *CAPEX* is a fairly complex and difficult procedure and, therefore, regulatory bodies avoid it. The starting point for the definition of an investment plan is growth in consumption and the

je porast potrošnje te zamjena postojeće opreme. Ti čimbenici se razlikuju kada je riječ o različitim energetskim subjektima te mogu značajno utjecati na rezultate primjene metode ravnanja prema mjerilu. Nadalje, iako se radi o istovrsnim investicijama i istoj razini investicija, na rezultate metoda ravnanja prema mjerilu može utjecati i različito vrijeme započinjanja investicije i dinamika realizacije investicije, kao i utvrđena razina kvalitete opskrbe. Kvaliteta opskrbe kao funkcija regulacije do sada se često promatrala kao zasebna funkcija od funkcije regulacije cijena usluga, iako iskustva pokazuju da regulatorna tijela sve više nastoje razviti integrirane modele regulacije kojima bi se izbjegli svi dosadašnji rizici primjene pojedine metode regulacije [9]. Tablica 1 prikazuje pojednostavljeni primjer izračuna dozvoljenog, odnosno od strane regulatornog tijela odobrenog prihoda regulatornim pristupom slaganja blokova. Vrijednosti za dozvoljene investicije (na godišnjoj razini od 1 000 milijuna kuna), početni *OPEX* (2 400 milijuna kuna) i amortizaciju od prethodnih investicija (700 milijuna kuna) koje su pri tome korištene na razini su vrijednosti HEP ODS-a [12]. Od vrijednosti prikazanih u literaturi pod [12] oduzeti su troškovi koji po procjeni autora otpadaju na priključke. Od regulatornih parametara utvrđeni su:

- regulatorno razdoblje od 4 godine,
- faktor učinkovitosti za *OPEX* u vrijednosti 90 %, što godišnje iznosi smanjenje *OPEX*-a 2,6 %,
- linearna amortizacija na razdoblje od 20 godina,
- stopa povrata od 7 %.

Iz tablice 1 vidljivo je da, ukoliko se svi parametri definiraju kako je prethodno rečeno, dozvoljeni prihod subjekata koji obavljaju regulirane djelatnosti kroz 4 godine regulatornog razdoblja ostaje na skoro istoj razini. Regulatorna politika, odnosno ocjena potrebne razine povećanja učinkovitosti, može imati značajan utjecaj na regulirani prihod energetskog subjekta.

### 3.2 Regulatorni pristup ukupnih troškova

U regulatornom pristupu ukupnih troškova regulatorno tijelo kada utvrđuje razinu opravdane učinkovitosti ne razlikuje između *OPEX*-a i *CAPEX* -a, stoga faktor učinkovitosti *X* primjenjuje na sumu *OPEX*-a i *CAPEX*-a, odnosno na ukupan trošak (*TOTEX*) (tablica 2). U ovom slučaju regulatorno tijelo ne mora utvrđivati odvojeno opravdanu razinu investicija za sljedeće regulatorno razdoblje, već analizu provodi za ukupne troškove. U ovom pristupu regulatorno tijelo utvrđuje *X*-faktor na osnovi razine učinkovitosti iz prethodnih regulator-

replacement of existing equipment. These factors differ among various energy entities and can significantly influence the results of the benchmarking method applied. Moreover, although this concerns the same types of investments and the same level of investment, the results of the benchmarking method can be affected by differing times for the beginning of investments and the dynamics of the implementation of the investments, as well as the determined level of the quality of the supply. Up to now, the quality of the supply as a function of regulation has been frequently viewed as a function that is separate from the function of the regulation of the prices for services, although experience shows that the regulatory bodies are increasingly attempting to develop integrated models of regulation that avoid all the risks inherent in the individual regulatory methods that have been applied [9]. Table 1 shows a simplified example of the calculation of allowed revenue, i.e. revenue authorized by the regulatory body, using the building block approach. The values for allowed investments (at an annual level of 1 000 million kunas), the initial *OPEX* (2 400 million kunas) and depreciation from previous investments (700 million kunas) were previously used at the level of the HEP Distribution System Operator (HEP ODS d,o.o.) [12]. From the values presented in the literature under [12], expenditures have been deducted that the authors consider to be connection costs. The following regulatory parameters have been established:

- a regulatory period of 4 years,
- a efficiency factor for *OPEX* with a value of 90 %, which amounts to an annual reduction in *OPEX* of 2,6 %,
- linear depreciation during a period of 20 years,
- a rate of return of 7 %.

From Table 1, it is evident that, when all the parameters are defined as above, the allowed revenue of a entities performing regulated activities during a 4-year regulatory period remains at nearly the same level. Thus, regulatory policy, i.e. the assessment of the necessary level of increasing efficiency, can have a significant impact on the regulated revenue of an energy entity.

### 3.2 The regulatory approach of total expenditure

In the regulatory approach of total expenditure, when the regulatory body determines the level of justified efficiency it does not differentiate between *OPEX* and *CAPEX*, and therefore the efficiency factor *X* is applied to the sum of *OPEX* and *CAPEX*, i.e. to the total expenditure (*TOTEX*) (Table 2). Therefore, in this case the regulatory body does not need to determine the justified levels of investment separately for the subsequent regulatory period but

nih razdoblja. Ukoliko je energetski subjekt uspio u prethodnim razdobljima podići razinu učinkovitosti, koju će zadržati i u budućem razdoblju, *X*-faktor će biti niži. Naime, ovo je značajna razlika u regulatornom pristupu u odnosu na pristup slaganja blokova u kojem se prije svega ocjenjuje opravdanost razine predviđenih investicija u budućem razdoblju, ali ne i učinkovita razina *CAPEX* -a.

analyzes the total expenditure instead. In this approach, the regulatory body determines the *X*-factor on the basis of the level of efficiency from the previous regulatory periods. If the energy entity has successfully achieved the specified level of efficiency during the previous periods, which will also be maintained during the future period, the *X*-factor will be lower. This is a significant difference in the regulatory approach in comparison to the building block approach, in which the justification of the level of the anticipated investments in the future period is assessed but not the efficiency level at the *CAPEX* level.

Tablica 2 – Pojednostavljen primjer izračuna dozvoljenog prihoda primjenom regulatornog pristupa ukupnog troška
Table 2 – A simplified example of the calculation of the allowed revenue through the application of the total expenditure regulatory approach

| **Regulatorni parametri / Regulatory parameters** | |
|---|---|
| Ukupni faktor učinkovitosti / Total efficiency factor | 88 % |
| Godišnja stopa porasta učinkovitosti / Annual rate of efficiency growth | 4 % |

| | **Godina / Year** | | | |
|---|---|---|---|---|
| | 0. | 1. | 2. | 3. |
| | ($10^6$ HRK) | ($10^6$ HRK) | ($10^6$ HRK) | ($10^6$ HRK) |
| *OPEX* / *OPEX* | 2 400,00 | 2 304,00 | 2 212,00 | 2 123,00 |
| Amortizacija / Depreciation | 700,00 | 672,00 | 645,00 | 619,00 |
| Povrat sredstava / Return on assets | 300,00 | 288,00 | 276,00 | 265,00 |
| **Dozvoljeni prihod / Allowed revenue** | 3 400,00 | 3 264,00 | 3 133,00 | 3 008,00 |

U ovom pristupu problem ocjenjivanja opravdanosti razine investicija je na svojevrstan način izbjegnut. Nadalje, budući da ovaj pristup ne razlikuje *OPEX* i *CAPEX*, moguće je da energetski subjekt postigne odgovarajuću razinu učinkovitosti balansirajući između *OPEX*-a i *CAPEX* -a, odnosno između, u klasičnom smislu teorije produktivnosti, rada i kapitala. Kod regulatornog pristupa ukupnih troškova, regulatorno tijelo ne mora razvijati kriterije za ocjenjivanje prijedloga investicija, već analizira *TOTEX*, koji uključuje i investicije, te utvrđuje *X*-faktor na osnovi analize *TOTEX*-a.

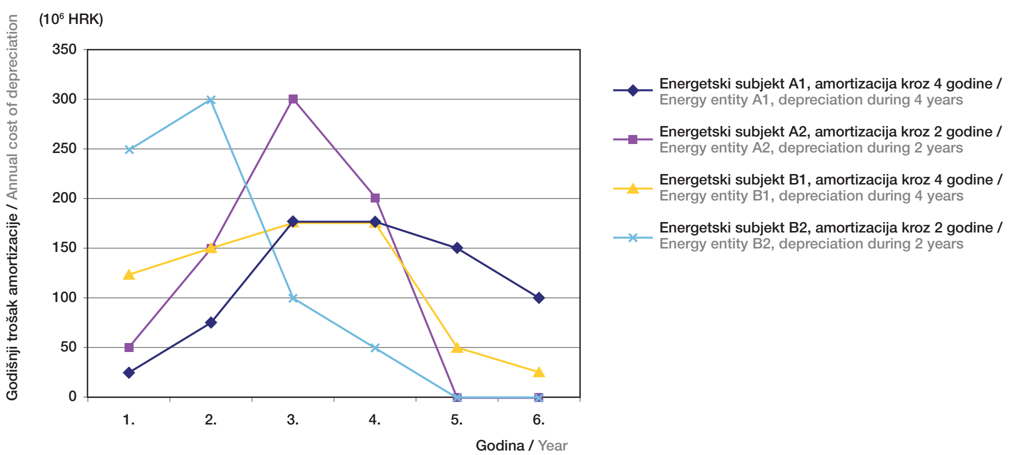
In this approach, the problem of assessing the justification of the level of investment is avoided in its own way. Furthermore, since this approach does not differentiate between *OPEX* and *CAPEX*, it is possible for an energy entity to achieve the suitable level of efficiency by balancing *OPEX* and *CAPEX* or labor and capital, in the classical sense of the theory of productivity. Therefore, in the regulatory approach of total expenditure, the regulatory body does not have to develop criteria for the assessment of an investment proposal but instead analyzes *TOTEX*, which also includes investment, and determines the *X*-factor on the basis of analysis of the *TOTEX*.

Tablica 3 – Pojednostavljen primjer utjecaja različite dinamike investiranja i amortizacijske politike na godišnji trošak amortizacije
Table 3 – A simplified example of the influence of various dynamics of investment and depreciation policies on the annual depreciation cost

| Godina / Year | Investicije / Investments ($10^6$ HRK) | Godišnji trošak amortizacije po investicijama / Annual depreciation cost according to investments ($10^6$ HRK) | | | Troškovi amortizacije / Depreciation costs ($10^6$ HRK) |
|---|---|---|---|---|---|
| **Energetski subjekt A1, amortizacija kroz 4 godine / Energy Entity A1, depreciation during 4 years** | | | | | |
| | | 1. | 2. | 3. | |
| 1. | 100 | 25 | | | 25 |
| 2. | 200 | 25 | 50 | | 75 |
| 3. | 400 | 25 | 50 | 100 | 175 |
| 4. | | 25 | 50 | 100 | 175 |
| 5. | | | 50 | 100 | 150 |
| 6. | | | | 100 | 100 |
| **Ukupno / Total** | 700 | 100 | 200 | 400 | 700 |
| | | | | | |
| **Energetski subjekt A2, amortizacija kroz 2 godine / Energy Entity A2, depreciation during 2 years** | | | | | |
| 1. | 100 | 50 | | | 50 |
| 2. | 200 | 50 | 100 | | 150 |
| 3. | 400 | | 100 | 200 | 300 |
| 4. | | | | 200 | 200 |
| 5. | | | | | 0 |
| 6. | | | | | 0 |
| **Ukupno / Total** | 700 | 100 | 200 | 400 | 700 |
| | | | | | |
| **Energetski subjekt B1, amortizacija kroz 4 godine / Energy Entity B1, depreciation during 4 years** | | | | | |
| 1. | 500 | 125 | | | 125 |
| 2. | 100 | 125 | 25 | | 150 |
| 3. | 100 | 125 | 25 | 25 | 175 |
| 4. | | 125 | 25 | 25 | 175 |
| 5. | | | 25 | 25 | 50 |
| 6. | | | | 25 | 25 |
| **Ukupno / Total** | 700 | 100 | 200 | 400 | 700 |
| | | | | | |
| **Energetski subjekt B2, amortizacija kroz 2 godine / Energy Entity B2, depreciation during 2 years** | | | | | |
| 1. | 500 | 250 | | | 250 |
| 2. | 100 | 250 | 50 | | 300 |
| 3. | 100 | | 50 | 50 | 100 |
| 4. | | | | 50 | 50 |
| 5. | | | | | 0 |
| 6. | | | | | 0 |
| **Ukupno / Total** | 700 | 500 | 100 | 100 | 700 |

Problem koji se javlja u regulatornom pristupu ukupnih troškova je vezan uz ročnost investicija. Naime, *CAPEX* se, uključujući amortizaciju i povrat sredstava, proteže kroz niz godina. Stoga bi prilikom primjene metoda ravnanja prema mjerilu analiza trebala u obzir uzeti razdoblje od nekoliko godina, a ne da se provodi na troškovima predviđenim samo za jednu godinu. Kao ilustrativni primjer dan je prikaz u kojem na *CAPEX* značajno utječe dinamika realizacije investicije, pri tome je prikazan samo trošak amortizacije, ali ne i povrat sredstava (tablica 3). Ukoliko bi se u analizi promatrala samo jedna godina, npr. druga godina realizacije investicije, energetski subjekt A1 bio bi učinkovitiji od energetskog subjekta B1, budući da su troškovi (75 milijuna kuna) energetskog subjekta A1 znatno niži od troškova (150 milijuna kuna) energetskog subjekta B1. Obrnuti slučaj bi se dogodio ukoliko bi se analiza provela u kasnijim godinama. Taj pojednostavljeni primjer naglašava važnost uključivanja dužeg razdoblja u analizu *TOTEX*-a metodom ravnanja prema mjerilu, što s praktične strane komplicira analizu budući da se mora analizirati veći skup podataka. Analiza se dodatno komplicira ukoliko se u obzir uzme različita računovodstvena praksa, što prikazuje tablica 3. Naime, energetski subjekti A1 i A2, odnosno B1 i B2, imaju istu dinamiku investiranja, međutim koriste različita amortizacijska razdoblja, stoga se njihov trošak amortizacije u pojedinoj godini značajno razlikuje (slika 3).

A problem that arises in the total expenditure regulatory approach is connected with investment maturity. *CAPEX*, including depreciation and return on assets, occurs over a series of years. Therefore, when applying the benchmarking method, analysis should take a period of several years into account and should not be performed for expenditures anticipated for only one year. An illustrative example is presented in which *CAPEX* significantly influences the dynamics of the investment, in which only the deprecation cost is shown and not the return on assets (Table 3). If only one year were considered in the analysis, for example the second year of the investment, Energy Entity A1 would be more efficient than Energy Entity B1, since the expenditures (75 million kunas) of Energy Entity A1 are significantly lower than the expenditures (150 million kunas) of Energy Entity B1. The reverse situation would occur if the analysis were performed in later years. This simplified example emphasizes the importance of including a longer period of analysis in the *TOTEX* benchmarking method, which from the practical aspect complicates analysis since it necessitates the analysis of a larger group of data. Analysis is further complicated insofar as various accounting practices are taken into account, as shown in Table 3. Energy Entities A1 and A2, i.e. B1 and B2, have the same dynamics of investment. However, they use different depreciation periods and, therefore, their depreciation costs in an individual year differ significantly (Figure 3).




**Slika 3**
Prikaz godišnjeg troška amortizacije za energetske subjekte čija je razina investiranja kumulativno jednaka, no godišnji trošak amortizacije se razlikuje

**Figure 3**
Annual depreciation costs for energy entities whose levels of investment are cumulatively equal but whose annual depreciation costs differ

Iako su prilikom razmatranja dva različita regulatorna pristupa korišteni poprilično jednostavni primjeri kroz koje su predočene različitosti u pristupima, primjeri odražavaju da se ulaganja trebaju razmatrati kroz duži vremenski rok. Na taj način može se provesti dosljedna regulatorna politika, ne samo u smislu utvrđivanja opravdane razine učinkovitosti, već i u smislu postizanja kontinuiranih

Although two fairly simple examples were used in analyzing the two different regulatory approaches, through which the differences in the approaches were presented, the examples demonstrate that investments must be analyzed over a long period of time. In this manner, it is possible to implement a consistent regulatory policy, not only in the sense of determining the justified level of efficiency but also

reguliranih cijena. Stabilna razina reguliranih cijena bez većih fluktuacija ne može se postići ukoliko su moguće česte promjene cijena usluga kao što je to slučaj s hrvatskim regulatornim okvirom, koji razmatra troškove subjekata koji obavljaju regulirane djelatnosti godinu za godinu. Naime, iako energetski subjekti nastoje, dugoročno gledajući, održavati istu razinu investicija na godišnjoj razini, njihovi troškovi su različiti od godine do godine, a time i razina dozvoljenog prihoda. Pitanje je na koji način će se HERA postaviti prema ovakvom problemu s kojim se susreću regulatorna tijela.

in the sense of achieving continuously regulated prices. A stable level of regulated prices without wide fluctuations cannot be achieved if it is possible to change the prices for services frequently, as is the case with the Croatian regulatory framework, which considers the expenditures of the entities performing regulated activities from year to year. Although the energy entities attempt to maintain the same level of investment on the annual level, viewed over the long-term, their costs differ from year to year and therefore the level of allowed revenue also differs. It is a question how the CERA will address this problem.

# 4 ULOGA HRVATSKE ENERGETSKE REGULATORNE AGENCIJE U DONOŠENJU PLANOVA RAZVOJA I IZGRADNJE

## 4.1 Zakonodavno rješenje

Hrvatski zakonodavac propisao je Zakonom o tržištu električne energije [8] da HEP OPS i HEP ODS donose planove razvoja i izgradnje za razdoblje od tri godine uz prethodnu suglasnost HERA-e na prijedlog planova. Međutim, zakonodavac ne prepoznaje nadležnost HERA-e u davanju suglasnosti za planove razvoja i izgradnje djelatnosti proizvodnje i opskrbe električnom energijom za tarifne kupce. Primjenjujući ovakvo zakonsko rješenje postavlja se pitanje na koji način će HERA razmatrati investicijske planove subjekata za proizvodnju i opskrbu električne energije i uključiti opravdana ulaganja u regulatornu osnovicu sredstava, budući da na njih temeljem Zakona [8] ne daje suglasnost, a primjenjuje istu metodu regulacije kao kod monopolnih djelatnosti – metoda priznatog troška. Ono što je potrebno napomenuti je da su tarifni sustavi, koje je donijela HERA, a ne zakonodavac, ulogu HERA-e u davanju suglasnosti na planove razvoja i izgradnje definirali kao identičnu za sve djelatnosti, iako to nije u skladu sa zakonskim odredbama. Nadalje, u tekstu svih tarifnih sustava navodi se da HERA daje suglasnost i na planove poslovanja svih djelatnosti iako pojam plan poslovanja Zakon [8] isto tako ne prepoznaje.

Takva razlika nadležnosti između zakonskih odredaba koje je utvrdio Hrvatski sabor i odredaba koje proizlaze iz podzakonskih akata koje je donijelo samo tijelo za sebe, u ovom slučaju HERA, potencira činjenicu da se prije donošenja drugog seta energetskih zakona nije detaljno analizirala uloga i pozicija HERA-e kao regulatornog tijela u energetskom sektoru RH kao niti regulacija energetskih djelatnosti kao disciplina sa svojim značajkama.

# 4 THE ROLE OF THE CROATIAN ENERGY REGULATORY AGENCY IN THE ADOPTION OF DEVELOPMENT AND CONSTRUCTION PLANS

## 4.1 Legislative solution

Croatian legislation stipulates that pursuant to the Electricity Market Act [8], the transmission system operator and the distribution system operator shall adopt development and construction plans for periods of three years, pending prior approval of the proposed plans by the CERA. However, the legislation does not recognize the authority of the CERA in issuing approval for the development and construction plans for the activities of the production and supply of electrical energy for tariff customers. Applying such a legal solution, the question arises concerning how the CERA will analyze the investment plans of the entities for the generation and supply of electrical energy and include the justified investment in the regulatory asset base, since according to the Law [8] it does not issue approval and applies the same method of regulation as for monopoly activities – the regulation of the rate of return. It should be mentioned that in the tariff systems which the CERA has adopted, and not the legislator, the roles of the CERA in issuing approval for development and construction plans are defined as identical for all activities, although this is not pursuant to the legal provisions. Furthermore, in the text of all the tariff systems, it is stated that the CERA also issues approval for the business plans of all activities, although the Law does not recognize the concept of a business plan [8].

Such differences in the specified authority between the legal provisions established by the Croatian Parliament and the provisions ensuing from the bylaws that the agency has issued for itself, in this case the CERA, emphasize the fact that the role

Naime, bitno je napomenuti da je HERA osnovana od strane RH kao javna ustanova što znači da joj je temeljem Zakona o ustanovama moguće dodijeliti javne ovlasti, odnosno prenijeti (delegirati) nadležnosti s državnog tijela [13]. Podjeljivanje javnih ovlasti uvijek otvara složeno pitanje smanjuje li se takvim ponašanjem opseg autoritativnog istupa države ili se pak ukupnost autoritativnog postupanja, a to znači i mogućnost uporabe prisile, proširuje. Bez obzira kojoj se konstataciji priklonili, mora se respektirati činjenica da je Zakon o ustanovama propisao da se zakonom ili na temelju zakona donesenom posebnom odlukom može javnoj ustanovi povjeriti da u sklopu djelatnosti radi koje je osnovana općim aktima uređuje određene odnose, da rješava u pojedinim upravnim stvarima o pravima, obvezama i odgovornosti fizičkih i pravnih osoba te da obavlja druge javne ovlasti.

Karakteristično je, također, da je Zakon o sustavu državne uprave, uz svoj temeljni pristup da poslove državne uprave obavljaju tijela državne uprave, propisao da se posebnim zakonom mogu određeni poslovi državne uprave prenijeti i pravnim osobama koje na temelju zakona imaju javne ovlasti [13]. Na temelju ovlasti iz posebnog zakona javne ustanove mogu obavljati najrazličitije poslove iz nadležnosti državnih tijela (posebno tijela državne uprave). Kad se razmotre odredbe Zakona o ustanovama, onda je vidljivo da je Zakon u složenom problemu podjeljivanja javnih ovlasti definirao dvoje:

– pravnu osnovu (izvor) javnih ovlasti – to su zakon, odnosno na temelju zakona donesena odluka predstavničkog tijela jedinica lokalne, područne samouprave,
– sadržaj javnih ovlasti – to je pravo da se općim aktima uređuju određeni odnosi, da se rješava u pojedinačnim upravnim stvarima o pravima, obvezama i odgovornosti određenih subjekata kao i eventualno pravo na obavljanje drugih javnih ovlasti.

Povjeravanje javnih ovlasti javnoj ustanovi znači za nju i određene dužnosti. U djelovanju javne ustanove ostvarivanje njezine posebne uloge (posebnog statusa) realizira se korištenjem javnih ovlasti i izvršavanjem dužnosti koje su joj u svezi s time nametnute. Javna ustanova mora obavljati javne ovlasti samo pod uvjetima, na način i u postupku koji je određen zakonom. Dakle, nemoguće joj je podzakonskim aktima dodjeljivati nadležnosti koje joj zakonski nisu pripisane kao što je to slučaj s pojedinim podzakonskim aktima proizašlim iz energetskih zakona.

and position of the CERA as a regulatory body within the energy sector of the Republic of Croatia and the regulation of energy activities as a discipline with specific characteristics had not been analyzed in detail prior to the adoption of the second set of energy acts. It is important to mention that the CERA was established by the Republic of Croatia as a public institution, which means that pursuant to the Institution Act it can be assigned public authority, i.e. delegated authority from the state entity [13]. The assignment of public authority always raises the complex question of whether the authority of the state is thereby diminished or whether the total authority, which means the option of the use of force, is expanded. In any case, it is necessary to respect the fact that the Institute Act stipulates that according to the law or pursuant to a law adopted by a special decision, a public institution may be entrusted, within the framework of the activities for which it has been established by enactments, to determine specific relationships; to resolve individual administrative issues about the rights, obligations and responsibilities of natural and legal persons; and to exercise other public authority.

It is also characteristic that the State Administrative System Act, in addition to the fundamental approach that the duties of state administration are to be performed by state administrative bodies, stipulates that pursuant to special legislation it is possible for specific duties of the state administration to be transferred to legal persons who have public authority pursuant to the law [13]. Therefore, based upon authorization from special legislation, public institutions are allowed to perform the most varied activities from the areas of the authority of the state bodies (especially state administrative bodies). When the provisions of the Institution Act are examined, it is evident that the Act has defined two issues within the complex problem of the assignment of public authority:

– the legal basis (source) of public authority – i.e. a ruling adopted pursuant to the law by the representative agency of the units of local and regional self-management,
– the content of public authority – i.e. the right to use enactments to determine relationships, to resolve issues concerning the rights, obligations and responsibilities of specific entities in individual administrative matters, as well as the eventual right to exercise other public authority.

The entrusting of public authority to a public institution means that specific duties are entrusted to it. In the operations of a public institution, it exercises its specific role (special status) through the exercise of public authority and the performance of duties that

**4.2 Kriteriji za davanje suglasnosti na planove razvoja i izgradnje reguliranih energetskih subjekata**

Energetski subjekti na koje se doneseni tarifni sustavi odnose nisu još dostavili HERA-i planove poslovanja, razvoja i izgradnje (koliko je poznato autorima) radi davanja suglasnosti. Rok za dostavu planova je 30. studenoga što proizlazi iz odredbi tarifnih sustava. Stoga se u ovom trenutku ne može razmatrati HERA-in odnos prema davanju suglasnosti na planove razvoja i izgradnje te koliko duboko je HERA spremna analizirati kriterije za odabir pojedinih investicija kao i da li će ući u analizu tehničkih rješenja ili će se povesti samo za odlukama energetskih subjekata kao instanci meritornih za definiranje kriterija od HERA-e. Isto tako ne može se razmatrati na koji način će HERA pristupiti utvrđivanju opravdanih, može se reći i učinkovitih, razina pojedinih troškova, te koje investicije će priznati u regulatornoj osnovici sredstava.

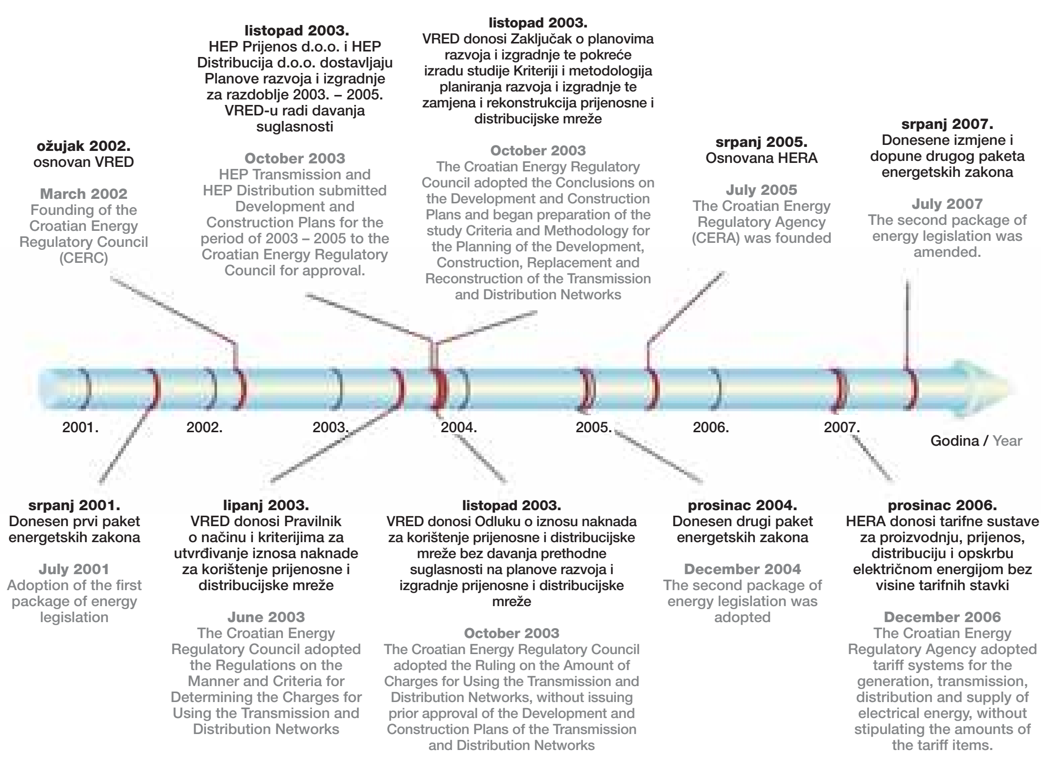
are thereby assigned to it. A public institution must exercise public authority only under the conditions, in such a manner and according to the procedure stipulated for it according to law. Therefore, it is not possible for enactments to assign authorization not stipulated by law, such as in the case of individual enactments resulting from energy legislation.

**4.2 Criteria for issuing approval for the development and construction plans of entities performing regulated activities**

The energy subjects to which the adopted tariff systems refer have still not submitted their plans for operations, development and construction (to the best of the authors' knowledge) to the CERA for approval. The deadline for the submission of the plans is November 30, according to the provisions of the tariff systems. Therefore, at this moment it is not possible to discuss the CERA's attitude toward issuing approval for development and construction plans and how deeply the CERA is prepared to analyze the criteria for choosing individual investments, as well as whether it will enter into analysis of the technical solutions itself or rely solely upon the decisions of the energy entities as sufficiently authoritative for defining its criteria. Similarly, it is not possible to discuss how the CERA will approach the determination of justified, it can be said effective, levels of individual expenditures, and which investments it will recognize in the regulatory asset base.

**Slika 4** Vremenski tijek donošenja propisa koji su vezani uz ulogu regulatornog tijela (VRED/HERA) u davanju suglasnosti na planove razvoja i izgradnje prijenosne i distribucijske mreže

**Figure 4** Time line of regulations adopted in connection with the role oh the regulatory body (CERC/CERA) in approving the development and construction plans of the transmission and distribution networks



#### 4.2.1 Iskustva Vijeća za regulaciju energetskih djelatnosti

Zakon o tržištu električne energije iz 2001. godine također je definirao da tadašnje regulatorno tijelo, Vijeće za regulaciju energetskih djelatnosti (VRED) [14], daje prethodnu suglasnost na plan razvoja i izgradnje prijenosne i distribucijske mreže. Hrvatski nezavisni operator sustava i tržišta d.o.o. (HNOSIT d.o.o.) i HEP Prijenos d.o.o. u 2003. godini proslijedili su Plan razvoja i izgradnje prijenosne mreže za razdoblje od 2003. do 2005. godine, odnosno HEP Distribucija d.o.o. Plan razvoja i izgradnje distribucijske mreže za razdoblje od 2003. do 2005. godine, VRED-u radi davanja prethodne suglasnosti. Budući da prije toga VRED nije zauzeo stav prema načinu na koji će pristupiti davanju prethodne suglasnosti na planove, VRED je pokrenuo izradu Kriterija i metodologija planiranja razvoja i izgradnje te zamjena i rekonstrukcija prijenosne i distribucijske mreže kojima se nastojalo na razvidan, jasan i dosljedan način utvrditi polazno stajalište regulatornog tijela vis-á-vis strategije razvoja prijenosne i distribucijske mreže kao i kriterija za rekonstrukciju postojećih objekata. Imajući u vidu da rad regulatornog tijela treba počivati na načelima razvidnosti, dosljednosti i stručnosti, VRED je zauzeo stajalište da je energetskom subjektu potrebno jasno definirati što se od njega očekuje tako da i buduća stajališta, odnosno odluke regulatornog tijela budu na svojevrstan način predvidljive. Tim više ukoliko se radi o kapitalno intenzivnim djelatnostima za čija ulaganja su potrebne dugoročnije analize kao i srednjoročan, odnosno dugoročan povrat investicijskih sredstava, koji se ujedno odražava i u iznosu tarifnih stavki.

Ilustrativni primjer VRED-ovog Zaključka iz 2003. godine koje je bilo ishodište za izradu Kriterija i metodologija planiranja razvoja i izgradnje te zamjena i rekonstrukcija prijenosne mreže, odnosno pokretanje dorade dostavljenog Plana razvoja i izgradnje prijenosne mreže za razdoblje od 2003. do 2005. godine, je sljedeći [15]:

I. Plan je potrebno donijeti u skladu sa Strategijom energetskog razvitka i Programom provedbe Strategije energetskog razvitka,

II. Da bi se provela procedura ocjene Plana i davanja suglasnosti na prijedlog Plana propisane člankom 12. stavak 1. Zakona o tržištu električne energije [14] potrebno je ispuniti sljedeće uvjete:

   1) definirati kriterije i metodologiju planiranja razvoja prijenosne mreže kao i metodologiju plana zamjene i rekonstrukcije koje će uključivati i ekonomske kriterije planiranja,

#### 4.2.1 Experience of the Croatian Energy Regulatory Council

The Electricity Market Act of 2001 also stipulated that the regulatory body at the time, the Croatian Energy Regulatory Council – CERC (Vijeće za regulaciju energetskih djelatnosti – VRED) [14], would issue prior approval for the development and construction plans of the transmission and distribution networks. In the year 2003, the Croatian Independent System and Market Operator – CISMO (Hrvatski nezavisni operator sustava i tržišta d.o.o. – HNOSIT d.o.o.) and HEP Transmission (HEP Prijenos d.o.o.) forwarded the Development and Construction Plan for the Transmission Network for the Period of 2003 to 2005, and HEP Distribution (HEP Distribucija d.o.o.) forwarded the Development and Construction Plan for the Distribution Network for the Period of 2003 to 2005 to the Croatian Energy Regulatory Council – CERC in order to obtain prior approval. Since the CERC had not previously taken a position regarding the manner in which it would approach the issue of prior approval for plans, it started work on the Criteria and Methodology for Planning the Development, Construction, Replacement and Reconstruction of Transmission and Distribution Networks, by which it attempted to determine the starting position of the regulatory body vis-à-vis the strategic development of the transmission and distribution networks as well as the criteria for the reconstruction of the existing facilities in a transparent, clear and consistent manner. Bearing in mind that the work of the regulatory body should be based upon the principles of transparency, consistency and expertise, the CERC assumed the position that it is necessary to provide a clear definition to the energy entity concerning what is expected of it so that the future positions, i.e. decisions, of the regulatory body would be predictable. This is even more important regarding investments in capital intensive activities, which would require long-term as well as medium-term analysis, i.e. the long-term return of invested assets, as also reflected in the amount of the tariff items.

An illustrative example of the CERC's conclusion from the year 2003, which was the starting point for devising the Criteria and Methodologies for Planning the Development, Construction, Replacement and Reconstruction of the Transmission Network, as well as preparing the final modifications of the submitted Development and Construction Plan for the Transmission Network for the Period from 2003 to 2005, is as follows [15]:

I. The plan must be adopted, pursuant to the Strategy for Energy Development and the Program for the Implementation of the Strategy for Energy Development,

što je u skladu s prijedlogom Mrežnih pravila hrvatskog elektroenergetskog sustava (koja u trenutku donošenja Zaključka nisu bila usvojena), a u kojima se takav kriterij jednoznačno ne definira,
2) planirati izgradnju objekata te zamjenu i rekonstrukcije objekata na način da predviđeni objekti zadovoljavaju definirane kriterije,
3) iskazati troškove HNOSIT-a d.o.o. odvojeno od planova HEP Prijenos d.o.o. te ih procijeniti u skladu s ulogom koju HNOSIT d.o.o. preuzima prema Zakonu o tržištu električne energije,

III. U daljnjim koracima potrebno je započeti sa sljedećim radnjama:

1) definirati zahtjeve koji se postavljaju na prijenosnu mrežu prvenstveno u smislu kvalitete električne energije isporučene izravnim i distributivnim kupcima (frekvencija, napon, raspoloživost mreže), te s obzirom na strateška pitanja razvoja mreže (samodostatnost, tretman susjednih mreža u planiranju, tranziti i uloga mreže u tržištu električne energije, izgradnja novih interkonekcija, modernizacija sustava, kriteriji izgradnje GIS postrojenja i dr.),
2) formirati jedinstvenu bazu podataka nužnu za planiranje razvoja mreže te definirati neke osnovne ulazne podatke bitne kod planiranja poput jediničnih troškova neisporučene električne energije, jediničnih cijena visokonaponske opreme, diskontne stope za potrebe planiranja i dr.,
3) za svaki objekt predviđen za izgradnju ili zamjenu i rekonstrukciju izraditi tehno-ekonomski elaborat iz kojeg bi proizašlo da li razmatrani objekt zadovoljava kriterije planiranja definirane Mrežnim pravilima i ostalim pripadnim dokumentima.

Zaključak sličnog karaktera VRED je donio i prilikom ocjene Plana razvoja i izgradnje distribucijske mreže za razdoblje od 2003. do 2005. godine. Na istoj sjednici VRED-a na kojoj je VRED donio navedene Zaključke, VRED je donio Odluku o iznosu naknada za korištenje prijenosne i distribucijske mreže [16] temeljem Zakona o tržištu električne energije iz 2001. godine [14]. Ta Odluka još uvijek je na snazi budući da je tarifni sustavi koje je donijela HERA nisu stavili van snage. Slika 4 prikazuje tijek donošenja relevantnih propisa i odluka koji se odnose na ulogu hrvatskog regulatornog tijela HERA-e, odnosno VRED-a, u donošenju planova razvoja i izgradnje prijenosne i distribucijske mreže.

II. In order to implement the procedures for the evaluation of the Plan and the issue of approval for the proposed Plan stipulated in Article 12, Paragraph 1 of the Electricity Market Act [14], the following prerequisites must be met:

1) to define the criteria and methodology for the planning of the development of the transmission network as well as the methodology for the replacement and reconstruction plan, which will include the economic criteria for planning, pursuant to the proposed Grid Code of the Croatian Electrical Energy System (which at the time of the adoption of the conclusion had still not been adopted), and in which such criteria are not defined unambiguously,
2) to plan the construction of facilities and the replacement and reconstruction of facilities in such a manner that the facilities meet the defined criteria,
3) to present the expenditures of the Croatian Independent System and Market Operator – CISMO (HNOSIT d.o.o.) separately from the plans of HEP Transmission (HEP – Prijenos d.o.o.) and to evaluate them according to the role that the CISMO assumes according to the Electricity Market Act,

III. In subsequent steps, it is necessary to begin the following activities:

1) to define the requirements that are established for the transmission network, primarily in the sense of the quality of the electrical energy to direct customers and customers connected to the distribution network (frequency, voltage and network availability), and regarding the strategic question of network development (self-sufficiency, the treatment of neighboring networks in planning; transit and the role of networks in the electrical energy market, the construction of new interconnections, the modernization of the system, the criteria for the construction of Geographical Information System [GIS] facilities etc.),
2) to establish a unified database necessary for the planning of network development and to define some basic input data required for planning, such as the unit prices of undelivered electrical energy, unit prices of high-voltage equipment, discount rates for the necessary planning etc.,
3) for each facility planned for construction, replacement or reconstruction, to prepare a technical/economic study which would show whether said facility meets the planning criteria defined by the Grid Code and other relevant documents.

### 4.2.2 Iskustva Hrvatske energetske regulatorne agencije

HERA za sada nije pristupila izradi sličnih kriterija ili stajališta o planovima razvoja i izgradnje HEP OPS-a i HEP ODS-a, niti je utvrdila svoj stav prema dubini analize (prema javno dostupnim informacijama). Nepostojanje unaprijed definiranih kriterija za davanje suglasnosti na planove moglo bi dodatno odgoditi donošenje iznosa tarifnih stavki za pojedine djelatnosti, budući da je davanje suglasnosti na planove preduvjet je za davanje mišljenja na prijedlog iznosa tarifnih stavki koje energetski subjekt dostavlja Ministarstvu gospodarstva, rada i poduzetništva (MINGORP), a MINGORP prosljeđuje HERA-i na mišljenje.

### 4.3 Stavovi Hrvatske energetske regulatorne agencije u rješavanju preduvjeta za primjenu metode priznatih troškova

Iz prethodno iznesene rasprave vezano uz regulatorni pristup gradnje blokova i regulatorni pristup ukupnih troškova vidljivo je da je vrlo značajna uloga regulatornoga tijela u utvrđivanju opravdane razine pojedinih regulatornih parametara. Utvrđena metoda priznatih troškova u donesenim tarifnim sustavima prepoznaje regulatorne parametre koji su ranije analizirani kao što su to – regulatorna osnovica sredstava, amortizacija i stopa povrata u vidu ponderiranog prosječnog troška kapitala. Tarifni sustavi definiraju da mišljenje o priznatim troškovima poslovanja (*OPEX*) i stopi povrata kapitala daje HERA, dok se kapitalni troškovi (*CAPEX*) – regulirana osnovica sredstava, tj. prinos od regulirane imovine i amortizacija utvrđuju na osnovi planova razvoja i izgradnje na koje HERA daje suglasnost. Utvrđena metoda regulacije ne poznaje faktor učinkovitosti kao regulatorni parametar metode.

Osim stava o dubini uplitanja u elemente planova poslovanja, razvoja i izgradnje, HERA bi trebala po mišljenju autora prilikom postupka davanja mišljenja na prijedlog iznosa tarifnih stavki po djelatnostima, između ostalog, svoj stav zauzeti i o sljedećem:

- je li obavljen razvidan i dosljedan nadzor nad razdvajanjem djelatnosti kako u tehničkom i tako i financijskom pogledu,
- opravdanoj razini stope povrata za svaku pojedinu djelatnost,
- koje investicije uključiti u regulatornu osnovicu sredstava, što uključuje i tumačenje pojedinih pojmova iz tarifnih sustava, kao što je npr. pojam nove investicije koje su sufinancirane, a uključene su u regulatornu osnovicu sredstava,
- opravdanoj razini troškova poslovanja (*OPEX*),
- i slično.

The CERC also adopted a conclusion of a similar character in the evaluation of the Development and Construction Plan for the Distribution Network for the Period from 2003 to 2005. At the same CERC session, at which the CERC adopted the previously mentioned conclusions, it also adopted the Decision on Fees for Using the Transmission and Distribution Networks [16], pursuant to the Electricity Market Act of 2001 [14]. This Decision is still in force, since the tariff systems that the CERA adopted are still in force. Figure 4 shows the course of the adoption of the relevant regulations and decisions that refer to the role of the Croatian Energy Regulatory Agency – CERA or the Croatian Energy Regulatory Council – CERC, in the adoption of development and construction plans for the transmission and distribution networks.

### 4.2.2 Experience of the Croatian Energy Regulatory Agency

For the present, the CERA has not started to develop similar criteria or positions on the development and construction plans of the transmission system operator and the distribution system operator, and has not defined its position toward in-depth analysis. The lack of previously defined criteria for issuing approval for plans could additionally postpone the adoption of the amounts of the tariff items for individual activities, since the issuing of approval for the plans is a prerequisite for issuing an opinion on the proposed amounts of the tariff items which an energy entity submits to the Ministry of the Economy, Labor and Entrepreneurship, and which the Ministry forwards to the CERA for an opinion.

### 4.3 Positions of the Croatian Energy Regulatory Agency in resolving the prerequisites for the application of the rate of return (*RoR*) method

From the previous discussion of the building block regulatory approach and the total expenditure regulatory approach, it is evident that the regulatory body has a highly significant role in the determination of the justified levels of individual regulatory parameters. The rate of return method in the adopted tariff systems recognizes the regulatory parameters that were analyzed previously, such as the regulatory asset base (*RAB*), depreciation and the rate of return regarding the weighted average cost of capital (*WACC*). The tariff systems stipulate that an opinion on the recognized operating expenditure (*OPEX*) and the rate of return on capital shall be issued by the CERA, while the capital expenditure (*CAPEX*) – the regulatory asset base, i.e. the revenue from regulated assets and depreciation shall be determined on the basis of the development and construction plans which shall be approved by the CERA. The established method of regulation does not recognize the efficiency factor as a regulatory parameter.

Jedan od bitnih preduvjeta za mogućnost uvođenja metode regulacije kao što je to metoda priznatih troškova je provođenje razvidnog i dosljednog razdvajanja djelatnosti u punom smislu – od razdvajanja imovine, osoblja do pridjeljivanja potraživanja po kreditima i sl. Jedan od problema je na koji način će HERA pristupiti davanju mišljenja na iznos tarifnih stavki za opskrbu električnom energijom ukoliko se zna da se nisu razdvojile djelatnosti distribucije i opskrbe električnom energijom te da HEP Operator distribucijskog sustava d.o.o. obavlja uz djelatnost distribucije i opskrbu električnom energijom, iako je zakonski rok za razdvajanje istih istekao (1. srpnja 2007. godine) [8].

Isti problem preslikava se i na utvrđivanje opravdane razine *OPEX*-a koji bi se trebao utvrditi na razini koja odražava učinkovitost poslovanja ili barem bi se ta razina tijekom godina trebala približiti učinkovitoj razini koja bi vrijedila da se djelatnost izloži tržišnom natjecanju i rizicima. Između ostalog, postavlja se pitanje što predstavlja *OPEX* u slučaju HEP Opskrbe d.o.o. koja obavlja djelatnost opskrbe samo za povlaštene kupce. Znači, taj trošak tarifni kupci uopće ne bi trebali snositi. Sa stajališta regulatornog tijela koje, uz zaštitu održivog poslovanja energetskog subjekta i omogućavanje nenarušenog tržišnog natjecanja, ima zadatak zaštite kupaca, bilo bi neopravdano priznati taj trošak kroz primjenu metode priznatih troškova i davanja pozitivnog mišljenja na prijedlog iznosa tarifnih stavki koji uključuju trenutačni trošak alociran unutar HEP Grupe na HEP Opskrbu d.o.o.

Nadalje, provedba razvidnog razdvajanja ima utjecaja i na *CAPEX* u svim djelatnostima. Naime, za svaku djelatnost HERA bi trebala utvrditi opravdanu razinu početne regulatorne osnovice sredstava, zatim amortizacijsku politiku i sredstva koja se tijekom regulatornog razdoblja dodjeljuju regulatornoj osnovi sredstva na koju se primjenjuje stopa povrata na kapital. Stopu koja se primjenjuje na srednju vrijednost regulatorne osnovice sredstava utvrđuje HERA na prijedlog energetskog subjekta. Problem koji se ovdje javlja je i utvrđivanje opravdane stope povrata, budući da se radi o djelatnostima koje su po svom karakteru različite – monopolne i tržišne, iz čega proizlaze različiti stupnjevi rizika u poslovanju kao i različiti uvjeti financiranja. Naime, iz opisa metode navedene u tarifnim sustavima nije razvidno koja će se stopa primijeniti i hoće li se ona razlikovati po djelatnostima, iako se radi o istom vertikalno organiziranom poduzeću HEP Grupi. Utvrđivanje stope povrata zahtijeva provođenje detaljnih analiza koje HERA još nije provela. Da bi HERA-in rad dobio na vjerodostojnosti i stručnosti potrebno je da HERA pravodobno, prije donošenje odluka i pod-

In addition to the position on the depth of involvement in the elements of the business, development and construction plans, it is the authors' opinion that the CERA should take a position on the following matters when issuing opinions on the proposed tariff amounts according to activities:

- whether transparent and consistent supervision has been performed over the unbundling of the technical and financial activities,
- the justified level of the rate of return for each individual activity,
- which investments should be included in the regulatory asset base, together with the interpretation of individual concepts from the tariff systems, such as, for example the concept of new investments that are co-financed and included in the regulatory asset base,
- the justified level of operating expenditures (*OPEX*),
- etc.

One of the essential prerequisites for the possible introduction of regulatory methods such as the rate of return method is the transparent and consistent unbundling of activities in the full sense – including the unbundling of assets, personnel, claims on loans etc. One of the problems is how the CERA will approach the issuing of opinions on the amount of tariff items for the supply of electrical energy if it knows that the activities of the distribution and supply of electrical energy have still not been unbundled and that the HEP Distribution System Operator performs the activity of the supply of electrical energy in addition to the activity of the distribution of electrical energy.

The same problem is also reflected in the determination of the justified level of *OPEX*, which should be determined at a level that reflects the efficiency of operations or at least this level during the year should approach a efficiency level that would be valid if the activity were subject to market competition and risks. Thus, among other things, the question is posed what *OPEX* represents in the case of HEP Supply (HEP Opskrba d.o.o.), which only performs the activity of supply for eligible customers. This means that tariff customers should not have to cover this expenditure. From the standpoint of the regulatory body which, in addition to safeguarding the sustainable operations of the energy entity and facilitating inviolable market competition, also has the task of protecting the customers, it would be unjustified to recognize this expenditure through the application of the rate of return method and issue a positive opinion on the proposed amounts of tariff items, which include the current expenditure allocated within the HEP Group for HEP Supply.

zakonskih akata, provede sve nužne analize koje u slučaju utvrđivanja metoda za izračun cijena usluga ponekad (po iskustvima drugih regulatornih tijela) traju i po 18 mjeseci [6].

Osim stope povrata, kod *CAPEX* -a, dilemu predstavlja tumačenje i drugih pojmova koje prepoznaje tarifni sustav, a isti nisu u dovoljnoj mjeri pojašnjeni, npr. vrijednost novih investicija koje su sufinancirane. Pretpostavlja se da ih sufinancira kupac. Trošak investicije koji je financirao kupac ne bi trebao ući u regulatornu osnovicu sredstava niti biti priznat kroz trošak amortizacije energetskog subjekta, budući da bi na taj način kupac plaćao investiciju dva puta – kroz trošak investicije i kroz tarifu. Upitno je na koji način će HERA pristupiti rješavanju problema investicija koje sufinancira kupac.

Navedeni primjeri pitanja na koje HERA mora odgovoriti prilikom davanja mišljenja na prijedlog iznosa tarifa i provođenja regulatorne politike samo su ilustrativni. Primjena ekonomske regulacije seže puno dublje i kompleksnija je od navedenih primjera te zahtijeva detaljne elaboracije i analize. No, i argumentirani stavovi koje HERA treba zauzeti prilikom rješavanja navedenih dilema iz opisanog primjera mogu značajno utjecati na razinu tarifnih stavki pojedinih djelatnosti te na raspodjelu troškova i prihoda između djelatnosti.

Furthermore, transparent division also has an impact on *CAPEX* in all activities. For each activity, the CERA would have to determine the justified level of the initial regulatory asset base, the depreciation policy and the assets that would be allocated to the regulatory asset base during the regulatory period, to which the rate of return on capital would be applied. The rate that is applied to the mean value of the regulatory asset base is determined by the CERA at the proposal of the energy entity. A problem that occurs here is the determination of the justified rate of return, since this concerns activities that differ in nature – monopolistic and market, from which there are different degrees of risks in operations as well as different conditions of financing. From the description of the methods stated in the tariff systems, it is not clear which rate will be applied and whether the rates will differ according to activities, although they concern the same vertically organized enterprise in the HEP Group. Determination of the rate of return requires detailed analysis. In order for the CERA's work to obtain credibility and professionalism, prior to adopting decisions and regulations the CERA must first perform all the necessary analyses in a timely manner, which in the case of the determination of the methods for the calculation of the prices for services sometimes (according to the experiences of other regulatory bodies) requires as long as 18 months [6].

In addition to the rate of return, regarding *CAPEX* there is a dilemma posed by the interpretation of other concepts that the tariff system recognizes, which are not explained to a sufficient extent, such as the value of new investments that are co-financed. It is assumed that they are co-financed by the customer. An investment expenditure that a customer has financed should not enter the regulatory asset base or be recognized as a depreciation expenditure of the energy entity. Otherwise, the customer would have to pay for the investment twice – through the investment expenditure and through the tariff. Therefore, it is a question how the CERA will approach the solution of the problem of investments that are co-financed by the customer.

The cited examples of questions to which the CERA must respond when issuing an opinion on the proposed amounts of tariffs and the implementation of regulatory policies are merely illustrative. The application of economic regulations ranges far deeper, is much more complex than the examples presented and requires more detailed elaboration and analysis. However, the argued positions that the CERA should assume when resolving the cited dilemmas from the example described could significantly affect the level of the tariff items for individual activities and the allocation of expenditures and revenues among the activities.

## 5 ZAKLJUČAK

U utvrđivanju reguliranih cijena primjenjuju se različite metode ekonomske regulacije i to prvenstveno u djelatnostima koje su po svom karakteru monopolne, znači prijenosu i distribuciji električne energije, a ne u djelatnostima proizvodnje i opskrbe koje su po svom karakteru tržišne djelatnosti. Sukladno tome, regulatorno tijelo u većini analiziranih država donosi ili daje suglasnost na planove razvoja i izgradnje monopolnih djelatnosti kao preduvjet za utvrđivanje cijena reguliranih usluga. Zakonska nadležnost regulatornog tijela da donosi ili daje suglasnost na planove razvoja i izgradnje energetskih subjekata u načelu ne daje odgovor koliko duboko je pravo regulatornog tijela da zadire u planove razvoja i izgradnje energetskih subjekata. Stoga se vrlo često u početku uvođenja regulatorne prakse postavlja pitanje koliko meritorno može biti regulatorno tijelo prilikom ulaska u rasprave o pojedinim koncepcijskim rješenjima, odnosno o pojedinim tehničkim pitanjima. Praksa u regulatornim tijelima u EU, odnosno članicama ERRA-e, s dužom regulatornom praksom od HERA-e pokazala je da su koncepcijska rješenja i kriteriji za izgradnju objekata u načelu odluka energetskog subjekta, dok regulatorno tijelo odobrava poslovne planove uključujući financijsko pokrivanje investicijskog plana. Paralelno odobravanju poslovnih planova, regulatorna tijela utvrđuju opravdanu razinu učinkovitosti te razinu kvalitete opskrbe kako se smanjenjem troškova ne bi smanjila i kvaliteta opskrbe.

Regulatorna politika može imati značajan utjecaj na budući prihod energetskog subjekta kroz utvrđivanje regulatorne osnovice sredstava u koju ulaze odobrena ulaganja te kroz utvrđeni faktor učinkovitosti. Odobrena razina ulaganja ima značajan odraz na visinu regulirane cijene koja proizlazi iz primijenjene regulatorne metode. Isto tako, ukoliko se jednom investicija prizna u *CAPEX*-u, a ne realizira se tijekom regulatornog razdoblja za koje je odobrena, nije opravdano opet uključiti je u *CAPEX* u sljedećem regulatornom razdoblju. Ako se radi o kratkom regulatornom razdoblju, kao što je to npr. jedna godina kako je predviđeno tarifnim sustavima koje je donijela HERA, postavlja se pitanje na koji način će regulatorno tijelo pratiti realizaciju investicije i njeno uključivanje u *CAPEX*. Naime, regulatorni pristupi analizirani u ovom članku pokazali su da je prilikom utvrđivanja *CAPEX*-a, odnosno razmatranja učinkovitosti pojedinog energetskog subjekta potrebno analizirati troškove kroz duže vremensko razdoblje. Takvom analizom, odnosno primjenom metoda ravnanja po mjerilu na složenijem skupu podataka, osigurala bi se vjerodostojnost i razvidnost postupanja regu-

## 5 CONCLUSION

In the determination of regulated prices, various methods of economic regulation are applied, primarily to activities that are by their nature monopolistic, i.e. the transmission and distribution of electrical energy, and not to the activities of generation and supply, which are by their nature market activities. Consequently, the regulatory bodies in the majority of the countries analyzed adopt or issue approval for the development and construction plans of monopolistic activities as a prerequisite for the determination of the prices for regulated services. The legal authority of a regulatory body to adopt or issue approval for the development and construction plans of energy entities in principle does not provide an answer to how much of a right the regulatory body has to interfere in the development and construction plans of energy entities. Therefore, the question is very often posed at the beginning of the introduction of regulatory practices concerning how competent a regulatory body can be when entering into a discussion on individual conceptual solutions, i.e. individual technical questions. The practice of the regulatory bodies in the EU or the members of the ERRA, with longer regulatory experience than the CERA, has shown that conceptual solutions and criteria for the construction of facilities are in principle the decision of the energy entity, while the regulatory body approves business plans including the financial coverage of the investment plan. Parallel to approving business plans, the regulatory body determines the justified level of efficiency and the level of the quality of supply, so that a reduction in expenditures does not lead to a reduction in the quality of the supply.

Regulatory policy can have a significant impact on the future revenue of an energy entity through the determination of the regulatory asset base in which approved investments are made and through the determination of the efficiency factor. The approved level of investment is significantly reflected in the amounts of the regulated prices determined from the application of a regulatory method. Similarly, if an investment is recognized in *CAPEX* and is not implemented during the regulatory period for which it has been approved, it is not justified to include it in *CAPEX* again for the subsequent regulatory period. If the regulatory period is short, such as, for example, one year, the question is posed how the regulatory body will monitor the implementation of the investment and its inclusion in *CAPEX*. The regulatory approaches analyzed in this article have demonstrated that when determining *CAPEX*, i.e. considering the efficiency of an individual energy entity, it is necessary to analyze expenditures over a long period of time. With such analysis, i.e. the application of the benchmarking method to a complex

latornog tijela tijekom procesa utvrđivanja cijena reguliranih usluga.

HERA, prilikom donošenja tarifnih sustava i opredjeljenja za metodu regulacije priznatih troškova, nije razmatrala posljedice koje regulatorni pristup može imati na dozvoljeni prihod reguliranih energetskih subjekata. Ujedno nije zauzela jasan i nedvosmislen stav prema nizu pitanja i dilema koje se mogu javiti tijekom postupka davanja suglasnosti na planove razvoja i izgradnje prijenosne i distribucijske mreže kao i tijekom davanja mišljenja na prijedlog energetskih subjekata o iznosu tarifnih stavki. Stoga je postupanje hrvatskog regulatornog tijela u postupku donošenja reguliranih cijena na temelju neke od poznatih metoda ekonomske regulacije još uvijek nedefinirano te nema dosadašnje prakse koja bi se mogla analizirati. Isto tako nepoznata je praksa HERA-e u smislu davanja suglasnosti na planove razvoja i izgradnje HEP OPS-a i HEP ODS-a.

Imajući u vidu dosadašnji tijek uvođenja ekonomske regulacije u Hrvatskoj te argumentaciju iz članka kao i iskustva drugih regulatornih tijela zaključak je autora da se zakonsko rješenje nužno mora mijenjati u više segmenata.

Prvo, da se prilikom definiranja nadležnosti HERA-e definiraju sve njene nadležnosti kroz zakonske odredbe, a ne da se naknadno iste utvrđuju kroz podzakonske akte koje donosi MINGORP ili HERA, kao što je to npr. slučaj s davanjem suglasnosti na planove poslovanja ili planove razvoja i izgradnje energetskog subjekta za proizvodnju i opskrbu električnom energijom.

Drugo, da se uloga HERA-e i primjena neke od poznatih metoda ekonomske regulacije ograniči samo na monopolne djelatnosti za koje su iste i razvijane. Naime, regulacija cijena u klasičnom smislu riječi gubi važnost u djelatnostima koje su po svom karakteru tržišne (u kojima tarifa značajno ovisi o parametrima na koje energetski subjekt ne može utjecati i koje regulatorno tijelo ne može nadzirat, kao što je to npr. cijena goriva) i u kojima regulatorno tijelo ne daje suglasnost na planove, kao što je to slučaj s proizvodnjom i opskrbom električnom energijom.

Treće, zakonsko rješenje sa samo polovično definiranim rokovima pokazalo se kao nedostatno. Naime, predviđen je rok za donošenje tarifnih sustava bez visine tarifnih stavki, a da nije predviđen rok za donošenje iznosa tarifnih stavki.

Posljedica ovakvog slijeda zakonskih rješenja je da su tarifni sustavi doneseni u prosincu 2006. godine, a da nisu prije toga napravljene simulacije

group of data, the credibility and transparency of the behavior of the regulatory body during the process of the determination of the prices for regulated services would be assured.

When adopting tariff systems and deciding upon the method for the regulation of the rate of return, the CERA did not consider the consequences that a regulatory approach can have on the allowed revenue of entities performing regulated activities. It also did not assume a clear and unambiguous position toward a series of questions and dilemmas that can arise during the procedure for the issuing of approval for the development and construction plans of the transmission and distribution networks as well as when issuing an opinion on proposals by energy entities on the amounts of tariff items. Therefore, the procedure by the Croatian Energy Regulatory Agency in the adoption of regulated prices on the basis of some of the recognized methods of economic regulation has still not been defined and there is no practical experience to date that could be analyzed. Similarly, the CERA's practices in the sense of issuing approval for development and construction plans for the transmission system operator and the distribution system operator are also unknown.

Bearing in mind the progress thus far in the introduction of economic regulation in the Republic of Croatia and the argumentation from the article, as well as the experiences of other regulatory bodies, it is the authors' conclusion that several segments of the legislative solution in the Republic of Croatia must be changed.

First, all of the CERA's authorities should be defined through legal provisions instead of determining them retrospectively through regulations issued by the Ministry of the Economy, Labor and Entrepreneurship or the CERA, such as, for example, the case of issuing approval for the business plans or the development and construction plans of an energy entity for the generation and supply of electrical energy.

Second, the role of the CERA and the application of some of the recognized methods of economic regulation should be limited to the monopolistic activities for which they were developed. Price regulation in the classical sense has diminished significance in activities with a market character (in which the tariff significantly depends upon parameters which the energy entity cannot influence and which the regulatory body cannot supervise, such as, for example, the price of fuel) and for which the regulatory body does not issue approval for plans, such as in the case of the generation and supply of electrical energy.

prihvaćene metode priznatih troškova s ulaznim podacima od HERA-e odobrenih planova razvoja i izgradnje reguliranih energetskih subjekata. Takva simulacija iznosa tarifnih stavki bi na razvidan način prikazala HERA-in stav prema priznavanju razine *OPEX*-a i *CAPEX*-a.

Third, a legal solution with only partially defined deadlines has proven to be insufficient. The deadline has been set for the adoption of tariff systems without the stipulation of the amounts of the tariff items, and the deadline for the adoption of the tariff items has not been set.

As a consequence of such a sequence of legislative solutions, the tariff systems were adopted in December 2006 without prior simulations based upon the accepted rate of return method and the input data came from development and construction plans of the entities performing regulated activities which the CERA had not previously approved. Such simulations of the amounts of the tariff items would present the CERA's position toward the recognized levels of *OPEX* and *CAPEX* in a transparent manner.

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Uredništvo primilo rukopis:
2007-08-14

Prihvaćeno:
2007-09-14

Manuscript received on:
2007–08–14

Accepted on:
2007–09–14

# NUMERIČKI PRORAČUN NISKOFREKVENCIJSKIH ELEKTROMAGNETSKIH PRIJELAZNIH POJAVA U ENERGETSKIM TRANSFORMATORIMA

# THE NUMERICAL CALCULATION OF LOW FREQUENCY ELECTROMAGNETIC TRANSIENT PHENOMENA IN POWER TRANSFORMERS

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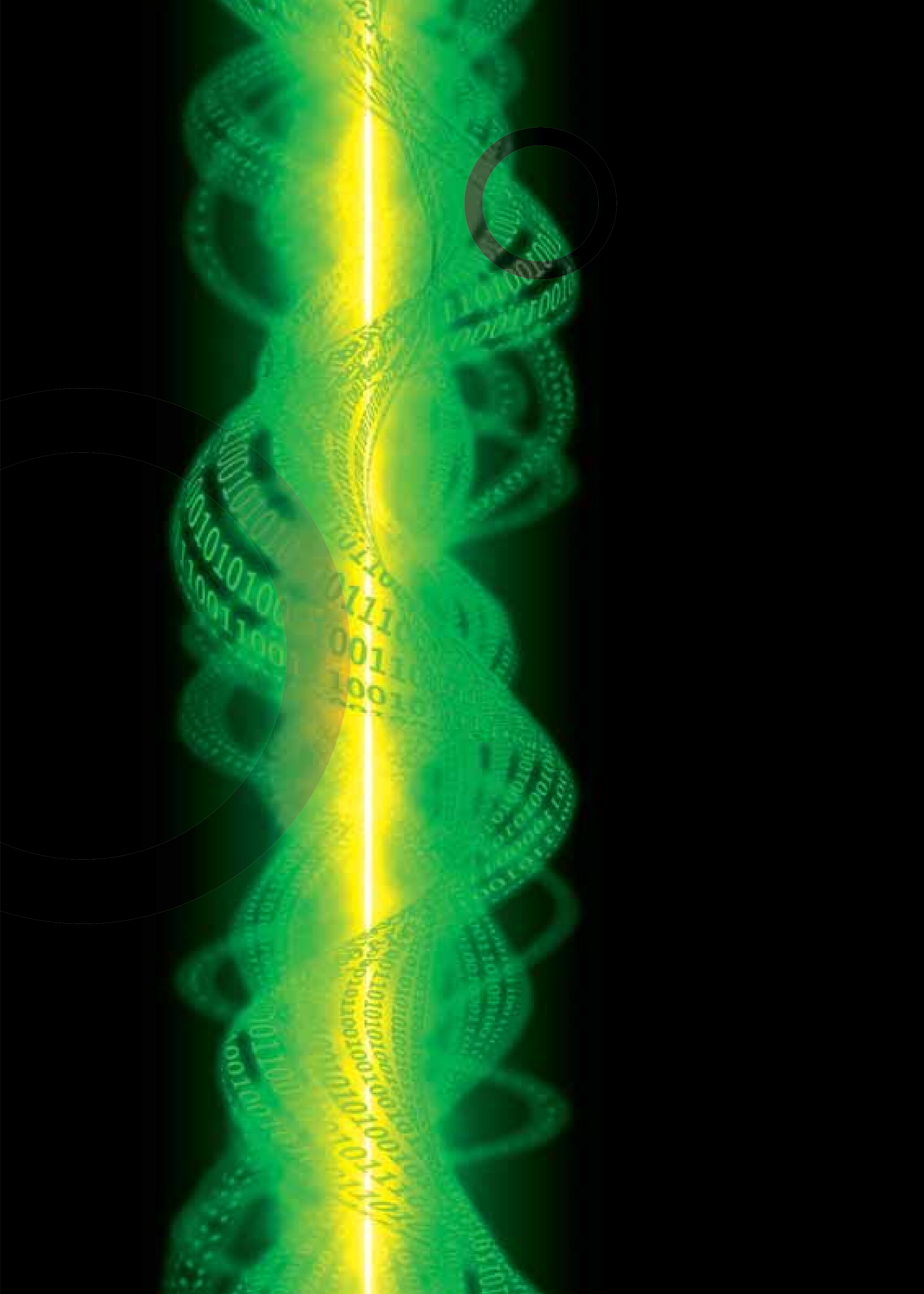
U radu je predstavljen model transformatora primjenjiv u niskofrekvencijskim elektromagnetskim prijelaznim pojavama, frekvencija reda oko 1 kHz. Analiziran je primjer uklapanja neopterećenog energetskog transformatora. Prvo je pokazan pojednostavljeni analitički pristup, a zatim, zbog njegova ograničenja, u analizu je uveden numerički pristup rješavanja krutih diferencijalnih jednadžbi koje opisuju prijelaznu pojavu. U oba slučaja je realiziran algoritam za generiranje valnih oblika varijabli stanja. Rezultati oba algoritma su uspoređeni s rezultatima MATLAB/Simulink/Power System Blockset, namjenskog programa za analizu elektromagnetskih prijelaznih pojava u elektroenergetskom sustavu. Razvijeni algoritam se može uspješno koristiti u ostalim niskofrekvencijskim prijelaznim pojavama gdje je glavni predmet analize nelinearni karakter transformatora: ferorezonancija, ispad tereta, kvarovi kod transformatora itd.

In this article, a transformer model is presented that is applicable to low frequency electromagnetic transient phenomena of up to 1 kHz. An example of the energization of a no-load transformer is analyzed. A simplified analytical approach is presented first. Due to the limitations of this approach, a numerical approach is introduced for the solution of the stiff differential equations that describe the transient phenomena. In both cases, algorithms have been developed for generating the waveforms of the state variables. The results of both algorithms are compared to the results of the MATLAB/Simulink/Power System Blockset for the analysis of electromagnetic transient phenomena in electrical energy systems. Developed algorithm with the introduced numerical approach can be used successfully in other low frequency transient phenomena where the main subject of analysis is the nonlinear character of the transformer: ferroresonance, load switch-off, transformer faults etc.

Ključne riječi: implicitno trapezno pravilo, krivulja magnetiziranja, krute diferencijalne jednadžbe, uklapanje transformatora
Key words: implicit trapezoidal rule, magnetization curve, stiff differential equations, transformer energization



# 1 UVOD

U niskofrekvencijske prijelazne pojave u transformatorima se obično ubrajaju uklapanje neopterećenih transformatora i ferorezonancija. U spomenutim prijelaznim pojavama parametar, koji dominantno utječe na rezultate prijelaznih pojava, je nelinearni induktivitet željezne jezgre transformatora. Kao posljedica nelinearnosti jezgre može doći do jakih strujnih udara prilikom uklapanja neopterećenih transformatora. Osnovne karakteristike struja uklopa transformatora su relativno velika amplituda, koja dostiže ekstremno i do 10 $I_{naz}$ kao i relativno velika duljina trajanja do postizanja stacionarnog stanja [1]. Ovakve struje često mogu uzrokovati nepotrebno djelovanje zaštitnih uređaja budući da mogu dostići vrijednosti struja kratkog spoja transformatora. S tim u vezi, danas su razvijene različite metode za razlikovanje struje uklapanja od struje kratkog spoja transformatora. Najčešće upotrebljavane tehnike razlikovanja su: harmonijska analiza struje (praćenje drugog harmonika struje) [2], energetske metode [3], metode magnetskih karakteristika transformatora [4], te suvremene tehnike koje se baziraju na upotrebi wavelet transformacije i neuronskih mreža [5], suvremenih korelacijskih algoritama [6], itd.

Posljedica struja uklapanja neopterećenih transformatora mogu biti privremeni, niskofrekvencijski, nesinusoidalni prenaponi [7], koji mogu značajno energetski preopteretiti metal-oksidne odvodnike prenapona koji su instalirani uz transformatore [8]. Zagrijavanje odvodnika bitno zavisi od promatrane konfiguracije mreže i od parametara sustava kao i odgovarajućih početnih uvjeta (trenutak uklopa transformatora, remanentni magnetizam transformatora itd.). Amplituda i duljina trajanja ovakvih privremenih napona, a samim time i zagrijavanje odvodnika prenapona, su znatno izraženiji u uvjetima slabih elektroenergetskih sustava.

Dodatno, uklapanje, odnosno isklapanje transformatora u električnim krugovima koje sadrže kapacitivnosti može dovesti do dugotrajnih ferorezonantnih prekostruja, odnosno prenapona. Tipični primjeri nastanka ferorezonancije nastupaju pri serijskoj kompenzaciji [9] ili pri isklapanju naponskih mjernih transformatora [10], te pri neregularnim sklopnim operacijama trofaznih prekidača (prijevremeni uklop/isklop jedne faze u mrežama sa izoliranom neutralnom točkom) [11].

S obzirom na iznesene praktične strane problema pri niskofrekvencijskim prijelaznim pojavama transformatora, potrebno je naročitu pozornost usmjeriti na pravilno modeliranje transformatora, odnosno simuliranje spomenutih pojava.

# 1 INTRODUCTION

Low frequency transient phenomena in transformers usually include the inrush currents of no-load transformers and ferroresonance. In these transients, the parameter with the dominant impact on the results is the nonlinear inductance of the iron core. As a consequence of the nonlinearity of the core, high inrush currents can occur when energizing no-load transformers. The basic characteristics of transformer inrush currents are relatively high amplitude, which in extreme cases can reach up to 10 $I_{rated}$ as well as the relatively long period of time until a steady state is reached [1]. Such currents frequently can cause unnecessary tripping to occur because they can reach the short-circuit current values of the transformers. In connection with this, various methods have been developed today for differentiating between transformer inrush current and short-circuit current. The most frequently used differentiation techniques are as follows: harmonic analysis of the current (second harmonic component) [2], power differential methods [3], methods based on transformer magnetizing characteristics [4], modern techniques that are based on the use of wavelet transform and neural networks [5], modern correlation algorithms [6] etc.

Consequences of no-load transformer inrush currents can be temporary, low frequency and nonsinusoidal overvoltages [7], which can significantly overload the metal oxide surge arresters that are installed next to the transformers [8]. The thermal stress on surge arresters depends significantly on the network configuration and the system parameters as well as the initial conditions (the instant of energization, remnant magnetism etc.). The amplitude and duration of such transient voltages, together with the thermal stress on surge arresters, are significantly more marked under the conditions of weak powersystems.

Additionally, energizing and de-energizing transformers in electrical networks with capacitance can lead to long term overcurrents or overvoltages due to ferroresonance. Typical examples of ferroresonance occur in series compensation [9], when switching off voltage measuring transformers [10] and due to the abnormal switching operations of three-phase switches (the premature energizing/de-energizing of a transformer phase in networks with an isolated neutral point) [11].

Taking into account the above-described practical aspect of the problem with the low frequency transient phenomena of transformers, particular attention should be devoted to the correct modeling of transformers, i.e. the simulation of these phenomena.

Kao što je već spomenuto, osnovna poteškoća u modeliranju energetskih transformatora je nelinearni karakter induktiviteta željezne jezgre transformatora. Ostali parametri transformatora: otpor i rasipni induktiviteti primarnog i sekundarnog namota kao i otpor koji reprezentira gubitke u željezu uzimaju se konstantnim [12]. Osnovna krivulja magnetiziranja transformatora dana je na slici 1a. Ova krivulja se može kvalitativno aproksimirati s dva pravca, slika 1b, koji predstavljaju tangente u nezasićenom i zasićenom području. Krivulja magnetiziranja energetskih transformatora ima jako oštar prijelaz iz nezasićenog u zasićeno područje. Ovo je posljedica konstruktivne izvedbe visokonaponskih energetskih transformatora. Naime, s porastom naponske razine, odnosno nazivne snage transformatora struja praznog hoda se smanjuje i iznosi [13] oko 5 % do10 % nazivne struje transformatora za transformatore snaga reda 100 kVA i opada sve do vrijednosti oko 0,47 % do 0,59 % nazivne struje transformatora za transformatore snage reda 500 MVA.

Pregled standardnih vrijednosti struje magnetiziranja za energetske transformatore različitih nazivnih snaga dan je tablicom 1. Struja prijelaza u zasićeno područje $i_z$ jednaka je nazivnoj struji pomnoženoj s faktorom ulaska u zasićenje $k$: $i_z = k \cdot i_{0naz}$, gdje je za energetske transformatore obično $1{,}05 \leq k \leq 1{,}3$. Dakle, koljeno krivulje magnetiziranja za energetske transformatore velikih snaga je razmješteno u veoma uskom području nazivne struje transformatora (reda 0,5 % do 1 % $i_{naz}$). Površina, koja je omeđena realnom krivuljom magnetiziranja i njenom aproksimacijom preko dva pravca, ovdje je reda svega oko 0,001 % ako uzmemo da je 100 % površina ispod cijele krivulje magnetiziranja u p.u. sistemu. Logična je posljedica ovako malih nazivnih struja praznog hoda da predstavljanje krivulje magnetiziranja preko svega dva pravca čini gotovo zanemarive pogreške u usporedbi s realnim predstavljanjem krivulje [14].

As previously mentioned, the basic difficulty in modeling power transformers is the nonlinear character of the inductance of the iron transformer core. The other transformer parameters, the resistance and leakage inductance of the primary and secondary windings as well as the resistance that represents losses in iron are assumed to be constant [12]. The basic transformer magnetizing curve is presented in Figure 1a. This curve can be qualitatively approximated with two straight lines, Figure 1b, that represent tangents in the unsaturated and saturated regions. The power transformer magnetizing curve has a very sharp transition from the unsaturated to the saturated regions. This is a consequence of the design of high voltage power transformers. With an increase in the voltage level or rated power of the transformer, no-load current is decreased and amounts to approximately 5 % to 10 % of the transformer rated current [13] for transformers with power ratings of 100 kVA and decreases to a value of approximately 0,47 % to 0,59 % of transformer rated current for transformers with power ratings of 500 MVA.

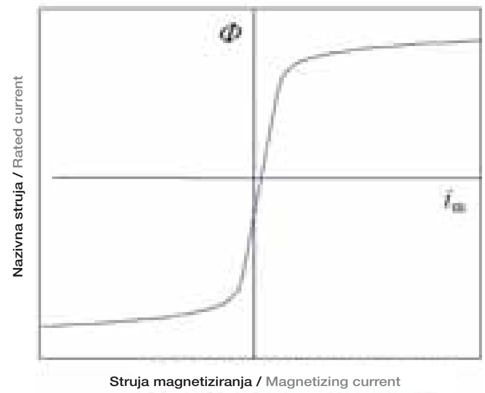
A review of the standard values of power transformer magnetizing currents for various rated powers is presented in Table 1. The transition current to the saturated region $i_z$ is equal to the rated current multiplied by the saturation factor $k$: $i_z = k \cdot i_{0rated}$, where usually for power transformers $1{,}05 \leq k \leq 1{,}3$. Thus, the bend in the magnetizing curve for a high power transformer is in a very narrow region of the transformer rated current (an order of 0,5 % to 1 % $i_{rated}$). The surface, which is bounded by the real magnetizing curve and its approximation by two straight lines is of an order here of only approximately 0,001 % if it is taken into account that 100 % of the surface below the magnetizing curve is in a p.u. system. A logical consequence of such low rated no-load currents is that it is possible to approximate the magnetizing curve using two straight lines with nearly negligible error in comparison to the real curve [14].

Tablica 1 –Tipične vrijednosti struje praznog hoda kao postotak nazivne struje za energetske transformatore
Table 1 –Typical values of no-load current as a percentage of rated current for power transformers

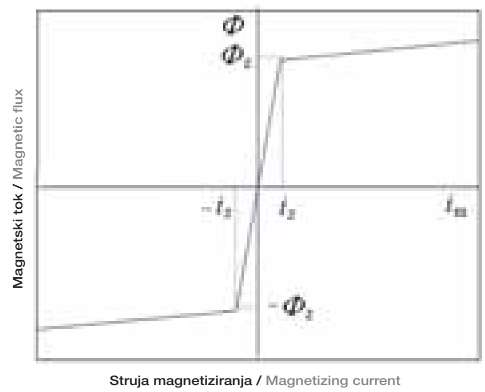
| | | | | | | |
|---|---|---|---|---|---|---|
| $S_{TR}$ (MVA) | 0,1 | 1,0 | 10 | 20 | 40 | 60 |
| $i_0$ (% $i_{naz/rated}$) | 5,0 – 8,0 | 1,75 – 2,32 | 0,35 – 1,1 | 0,8 – 1,2 | 0,65 – 0,94 | 0,58 – 0,84 |
| $S_{TR}$ (MVA) | 80 | 100 | 150 | 200 | 300 | 500 |
| $i_0$ (% $i_{naz/rated}$) | 0,54 – 0,77 | 0,51 – 0,73 | 0,47 – 0,67 | 0,51 – 0,64 | 0,49 – 0,61 | 0,47 – 0,59 |

**Slika 1**
Krivulja magnetiziranja transformatora a) i njena aproksimacija preko dva pravca b)
**Figure 1**
Magnetizing curve of transformer a) and its approximation via two straight lines b)

a)

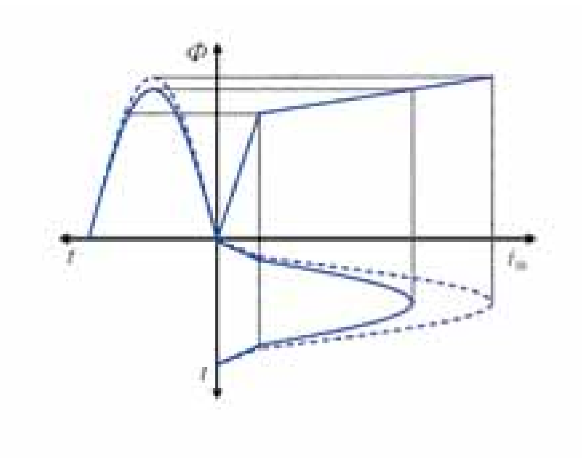



b)

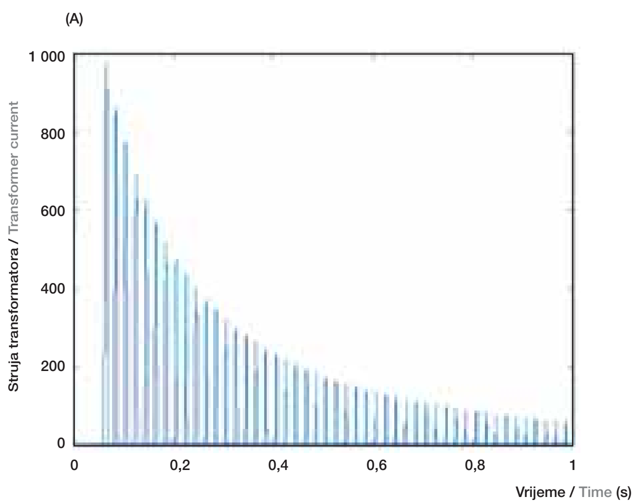



Posljedica nelinearnog karaktera željezne jezgre transformatora je nesinusoidalna struja magnetiziranja transformatora pri sinusoidalnom naponu napajanja, tj. sinusoidalnom magnetskom toku, što je jasno ilustrirano na slici 2. Na istoj slici su prikazana dva oblika struje magnetiziranja za dvije različite tjemene vrijednosti magnetskog toka. Tijekom prijelazne pojave uklapanja transformatora kada magnetski tok može poprimi vrijednosti i veće od svoje dvostruke nazivne vrijednosti [15], dolazi do jakih strujnih udara transformatora, što je pokazano na slici 3.

A consequence of the nonlinear character of the iron transformer core is the nonsinusoidal transformer magnetizing current at the sinusoidal supply voltage, i.e. sinusoidal magnetic flux, which is clearly illustrated in Figure 2. In the same figure, two forms of magnetizing current are presented for two different peak values of the magnetic flux. During the transient phenomena of transformer energization, when the magnetic flux can acquire values greater than twice its rated value [15], high inrush current occurs, as presented in Figure 3.




**Slika 2**
Nesinusoidalna struja magnetiziranja transformatora
**Figure 2**
Nonsinusoidal transformer magnetizing current




**Slika 3**
Tipičan valni oblik struje uklapanja transformatora
**Figure 3**
Typical waveform of transformer inrush current

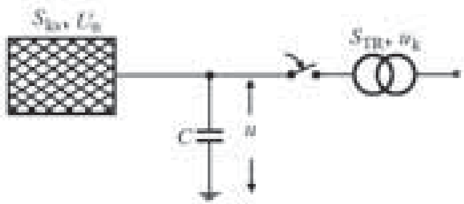
## 2 MATEMATIČKI MODEL PRI UKLAPANJU NEOPTEREĆENOG ENERGETSKOG TRANSFORMATORA

U ovom poglavlju će se analizirati matematički model pri uklapanju neopterećenog energetskog transformatora, slika 4a i b. Između transformatora i točke priključka na mrežu postoji kapacitet $C$, kojim se ekvivalentira prilaz kabelskim ili nadzemnim vodom, kapacitet kondenzatorskih baterija i sl.

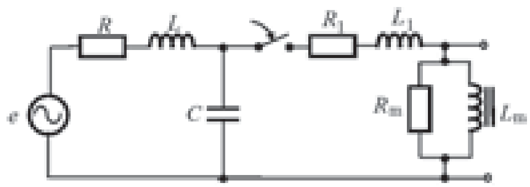
## 2 MATHEMATICAL MODEL OF THE ENERGIZATION OF A NO-LOAD POWER TRANSFORMER

This chapter presents an analysis of a mathematical model of the energization of a no-load power transformer, Figures 4a and b. Between the transformer and the connection point to the network, there is a capacity $C$, which is equivalent to the capacity of a cable or overhead approach line, the capacitance of the capacitors etc.

**Slika 4** Uklapanje neopterećenog energetskog transformatora
**Figure 4** The energization of a no-load power transformer




a) Shema uklapanja transformatora na mrežu / Simplified electrical circuit of transformer energization




b) Odgovarajuća zamjenska shema slike a) / Equivalent electrical circuit of Figure a)

Parametri mreže se dobivaju iz podataka o snazi tropolnog kratkog spoja u točki priključka:

The network parameters are obtained from data on the three-phase short-circuit power at the point of connection:

$$L = \frac{U_n^2}{S_{ks} \cdot \omega} \quad . \tag{1}$$

Pretpostavlja se da je odnos $X / R$ za danu mrežu poznat, na osnovi kojega se određuje otpor $R$.

Na osnovi poznate nazivne snage transformatora $S_{TR}$, te napona kratkog spoja moguće je odrediti rasipni induktivitet tansformatora:

It is assumed that the ratio of $X / R$ for the given network is known, on the basis of which we determine resistance $R$.

On the basis of the known transformer rated power $S_{TR}$ and the short-circuit voltage, it is possible to determine the leakage inductance of the transformer:

$$L_1 = \frac{U_n^2}{S_{TR} \cdot \omega} \cdot u_k \, . \tag{2}$$

Ostali podaci, djelatni otpor primarnog namota transformatora $R_1$, djelatni otpor izazvan gubicima u željezu $R_m$, te nelinearni induktivitet željezne

Other data, the effective resistance of the primary transformer winding $R_1$, the effective resistance due to iron core losses $R_m$, and the nonlinear inductance

jezgre transformatora $L_m$, inače definirana krivuljom magnetiziranja $\Phi$-$i_m$ ($\Phi$ je glavni ulančeni magnetski tok, $i_m$ je struja magnetiziranja transformatora), lako se mogu odrediti mjerenjem ili su već dani od strane proizvođača. Ovaj nelinearni induktivitet aproksimiran je s dva pravca u $\Phi$-$i_m$ koordinatnom sustavu, slika 2, što je za energetske transformatore u praksi uglavnom prihvatljivo. Točka ($i_z$, $\Phi_z$) predstavlja kritičnu točku pri prelasku iz nezasićenog u zasićeno područje željezne jezgre. Koeficijenti pravaca ustvari predstavljaju induktivitete u nezasićenom ($L_{m1}$, const$_1$) i zasićenom području ($L_{m2}$, const$_2$). Na ovaj način dobivamo funkcionalnu ovisnost struje magnetiziranja o magnetskom toku kao (funkcijom *sign* osiguravamo pozicioniranje u odgovarajućem kvadrantu):

of the transformer iron core $L_m$, otherwise defined by the magnetizing curve $\Phi$-$i_m$ ($\Phi$ is the main linkage magnetic flux, $i_m$ is the transformer magnetizing current), can easily be determined through measurement or are already provided by the manufacturer. This nonlinear inductance is approximated with two straight lines in the $\Phi$-$i_m$ coordinate system, Figure 2, which is generally acceptable in practice for power transformers. Point ($i_z$, $\Phi_z$) represents the critical point at the transition from the unsaturated region to the saturated region of the iron core. The straight lines coefficients actually represent inductances in the unsaturated region $L_{m1}$, const$_1$ and saturated region $L_{m2}$, const$_2$. In this manner, we obtain the functional dependence of the magnetizing current on the magnetic flux (we define the position in the corresponding quadrant with the *sign* function) as follows:

$$i_m = \frac{1}{L_{m1}}\Phi , \ |\Phi| \le \Phi_z , \tag{3}$$

$$i_m = \frac{1}{L_{m2}}\Phi + \mathrm{sign}(\Phi)\left(\frac{1}{L_{m1}} - \frac{1}{L_{m2}}\right)\Phi_z , \ |\Phi| > \Phi_z . \tag{4}$$

## 3 ANALITIČKI PRISTUP

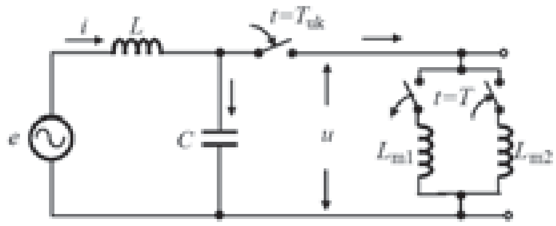
Radi jednostavnosti zanemarit će se sve aktivne elemente sa slike 4b. Dakle, pri prijelaznoj pojavi uklapanja transformatora ako trenutačna vrijednost magnetskog toka, po apsolutnoj vrijednosti premaši kritičnu vrijednost $\Phi_z$, induktivnost transformatora se mijenja sa $L_{m1}$ na $L_{m2}$. To ustvari znači da se trenutak kada magnetski tok dostigne vrijednost $\Phi_z$ može uzeti kao vrijeme $t=T>T_{uk}$ isklapanja induktiviteta $L_{m1}$ odnosno uklapanja induktiviteta $L_{m2}$. Ekvivalentna shema bi u tom slučaju izgledala kao na slici 5. Slično, pri smanjenju magnetskog toka ispod vrijednosti $\Phi_z$ isključuje se induktivitet $L_{m2}$ i uključuje induktivitet $L_{m1}$.

## 3 ANALYTICAL APPROACH

For the purpose of simplicity we shall ignore all the active elements from Figure 4b. In the transient phenomena during transformer energization, if the instantaneous value of the magnetic flux in terms of absolute value exceeds the critical value of $\Phi_z$, the transformer inductance changes from $L_{m1}$ to $L_{m2}$. This actually means that the moment when the magnetic flux reaches the value of $\Phi_z$ can be taken as the time $t=T>T_{uk}$ of switching off the inductance $L_{m1}$, respectively the time of switching on the inductance $L_{m2}$. In this case, an equivalent diagram would look like the one presented in Figure 5. Similarly, when the magnetic flux is decreased below the value of $\Phi_z$, inductance $L_{m2}$ is switched off and inductance $L_{m1}$ is switched on.

**Slika 5**
Uklapanje transformatora – pojednostavljeni model

**Figure 5**
Transformer energization – simplified model




Dakle, promjena trenutačne vrijednosti magnetskog toka pri prelaznoj pojavi uvjetuje prelaske s jednog na drugi pravac što u diferencijalnim jednadžbama koje opisuju ponašanje električnih krugova ustvari znači promjenu koeficijenata. Proces počinje s induktivitetom $L_{m1}$. Uz oznake kao na slici 5 dobiju se diferencijalne jednadžbe koje opisuju ponašanje električnog kruga u proizvoljnom trenutku $t \geqslant T_{uk}$, gdje je $t=T_{uk}$ trenutak uklapanja prekidača :

Therefore, in transient phenomena transition from one straight line to another is conditional upon change in the instantaneous value of the magnetic flux, which in differential equations that describe the behavior of electric circuits actually signifies coefficient changes. The process begins with the inductance $L_{m1}$. Using the same symbols as in Figure 5, differential equations are obtained that describe the behavior of the electric circuit at the arbitrary moment $t \geqslant T_{uk}$ , where $t=T_{uk}$ is the moment that the switch is turned on:

$$E_m \cos \omega t = \frac{d^2 \Phi}{dt^2} + \frac{1}{C}\left(\frac{1}{L_{m1}} + \frac{1}{L}\right)\frac{d\Phi}{dt}, \; |\Phi| \leq \Phi_z, \tag{5}$$

$$E_m \cos \omega t = \frac{d^2 \Phi}{dt^2} + \frac{1}{C}\left(\frac{1}{L_{m2}} + \frac{1}{L}\right)\frac{d\Phi}{dt}, \; |\Phi| > \Phi_z. \tag{6}$$

Rješava se prvo diferencijalna jednadžba (5). Uz izraz za prirodnu kružnu frekvenciju kruga:

Differential equation (5) is solved first. When the natural circular frequency of the circuit is as follows:

$$\omega_{01} = \sqrt{\frac{1}{C}\left(\frac{1}{L_{m1}} + \frac{1}{L}\right)}, \tag{7}$$

dobiva se opće rješenje diferencijalne jednadžbe (5):

the general solution to equation (5) is obtained:

$$\Phi(t) = a + b\cos\omega_{01}t + c\sin\omega_{01}t + B\sin\omega t\,. \tag{8}$$

Konstante $a$, $b$ i $c$ određuju se iz početnih uvjeta:

Constants $a$, $b$ and $c$ are determined from the initial conditions:

$$\Phi(T_{uk}) = \Phi_0 , \tag{9}$$

$$u(T_{uk}) = \left.\frac{d\Phi}{dt}\right|_{t=T_{uk}} = U_0 , \tag{10}$$

$$i_C(T_{uk}) = C\left.\frac{du}{dt}\right|_{t=T_{uk}} = C\left.\frac{d^2\Phi}{dt^2}\right|_{t=T_{uk}} = I_{C0} . \tag{11}$$

Napon $U_0$ i struja $I_{C0}$ se određuju iz stanja prije uklapanja prekidača:

Voltage $U_0$ and current $I_{C0}$ are determined from the state prior to turning on the switch:

$$U_0 = \frac{E_m}{1-\omega^2 LC}\cos\omega T_{uk} , \tag{12}$$

$$I_{C0} = -\frac{\omega C E_m}{1-\omega^2 LC}\sin\omega T_{uk} . \tag{13}$$

Koeficijenti $a$, $b$ i $c$ se dobivaju iz matrične jednadžbe koja se formira na osnovi jednadžbi (9) do (13):

Coefficients $a$, $b$ and $c$ are obtained from the matrix equation formed on the basis of equations (9) to (13):

$$\boldsymbol{M} = \boldsymbol{K}^{-1}\cdot\boldsymbol{N}, \tag{14}$$

gdje su matrice ***M***, ***K*** i ***N*** redom:

where matrices ***M***, ***K*** and ***N*** are as follows:

$$\boldsymbol{M} = \begin{bmatrix} a \\ b \\ c \end{bmatrix} , \tag{14a}$$

$$\boldsymbol{K} = \begin{bmatrix} 1 & \cos\omega_{01}T_{uk} & \sin\omega_{01}T_{uk} \\ 0 & -\omega_{01}\sin\omega_{01}T_{uk} & \omega_{01}\cos\omega_{01}T_{uk} \\ 0 & -\omega_{01}^2\cos\omega_{01}T_{uk} & -\omega_{01}^2\sin\omega_{01}T_{uk} \end{bmatrix} , \tag{14b}$$

$$\boldsymbol{N} = \begin{bmatrix} \Phi_0 - B\sin\omega T_{uk} \\ U_0 - B\omega\cos\omega T_{uk} \\ I_0/C + B\omega^2\sin\omega T_{uk} \end{bmatrix} . \tag{14c}$$

Kada se odrede konstante $a$, $b$ i $c$ tada se za vremenski oblik magnetskog toka $\Phi(t)$, napona $u(t)$ na transformatoru i struje kondenzatora $i_C(t)$ dobiva:

When constants $a$, $b$ and $c$ are determined, the magnetic flux $\Phi(t)$, transformer voltage $u(t)$ and condenser current $i_C(t)$ waveforms as a function of time are then as follows:

$$\Phi(t) = a + b\cos\omega_{01}t + c\sin\omega_{01}t + B\sin\omega t\,, \tag{15}$$

$$u(t) = -b\omega_{01}\sin\omega_{01}t + c\omega_{01}\cos\omega_{01}t + B\omega\cos\omega t\,, \tag{16}$$

$$i_C(t) = C\left(-b\omega_{01}^2\cos\omega_{01}t - c\omega_{01}^2\sin\omega_{01}t - B\omega^2\sin\omega t\right). \tag{17}$$

U jednadžbi (8) konstanta $a$ predstavlja istosmjernu komponentu magnetskog toka, $b$, $c$ i $\omega_{01}$ konstante kojima je definiran vlastiti odziv, a $B$ i $\omega$ konstante kojima je definiran prinudni odziv u rješenju za magnetski tok. Posljednje tri jednadžbe vrijede sve dok je zadovoljeno $|\Phi| \leq \Phi_z$. U protivnom, kada bude $|\Phi| > \Phi_z$ tada ponašanje električnog kruga opisuje diferencijalna jednadžba (6) opisuje stanje ravnoteže s parametrom $L_{m2}$ umjesto $L_{m1}$. Početni uvjeti za novu diferencijalnu jednadžbu (6) su posljednje trenutačne vrijednosti rješenja prvobitne jednadžbe (5). Rješenja diferencijalne jednadžbe (6) se dobivaju istim postupkom kao rješenja jednadžbe (5). Analogno se razmišlja pri ponovnom smanjenju magnetskog toka ispod vrijednosti $\Phi_z$ sa odgovarajućim početnim uvjetima koji su određeni posljednjim trenutačnim vrijednostima stare diferencijalne jednadžbe.

Struja magnetiziranja transformatora $i_m$ određuje se na osnovi relacija (3) i (4).

Generalno se može organizirati algoritam koji bi prateći vrijednost trenutačnog magnetskog toka rješavao diferencijalne jednadžbe (5) i (6) s odgovarajućim početnim uvjetima. Uvodeći težinske koeficijente $k_1$ i $k_2$ koji bi uzimali vrijednosti 0 ili 1 moguće je načiniti petlju koja bi stalno računala vrijednost magnetskog toka u zasićenom ili nezasićenom području vodeći računa o odgovarajućim početnim uvjetima.

Remanentni magnetizam transformatora $\Phi_{rem}$ moguće je uvažiti ako se u proračun krene s tom vrijednošću, $\Phi(T_{uk}) = \Phi_{rem}$. Histerezna petlja je zanemarena, što je u praktičkim primjerima za energetske transformatore sasvim prihvatljivo [16].

In equation (8), constant $a$ represents the DC component of the magnetic flux, $b$, $c$ and $\omega_{01}$ are the constants by which the self response is defined, and $B$ and $\omega$ are the constants by which the forced response is defined in the solution for the magnetic flux. The last three equations are valid until the condition of $|\Phi| \leq \Phi_z$ is met. Otherwise, when $|\Phi| > \Phi_z$, differential equation (6) describes the behavior of the electric circuit with the parameter $L_{m2}$ instead of $L_{m1}$. The initial conditions for a new differential equation (6) are the last instantaneous values from the solution of equation (5). The solution to differential equation (6) is obtained according to the same procedure as the solution to equation (5). An analogous procedure is used when the magnetic flux is again reduced below the value of $\Phi_z$ with the corresponding initial conditions that are determined using the instantaneous values of the previous differential equation.

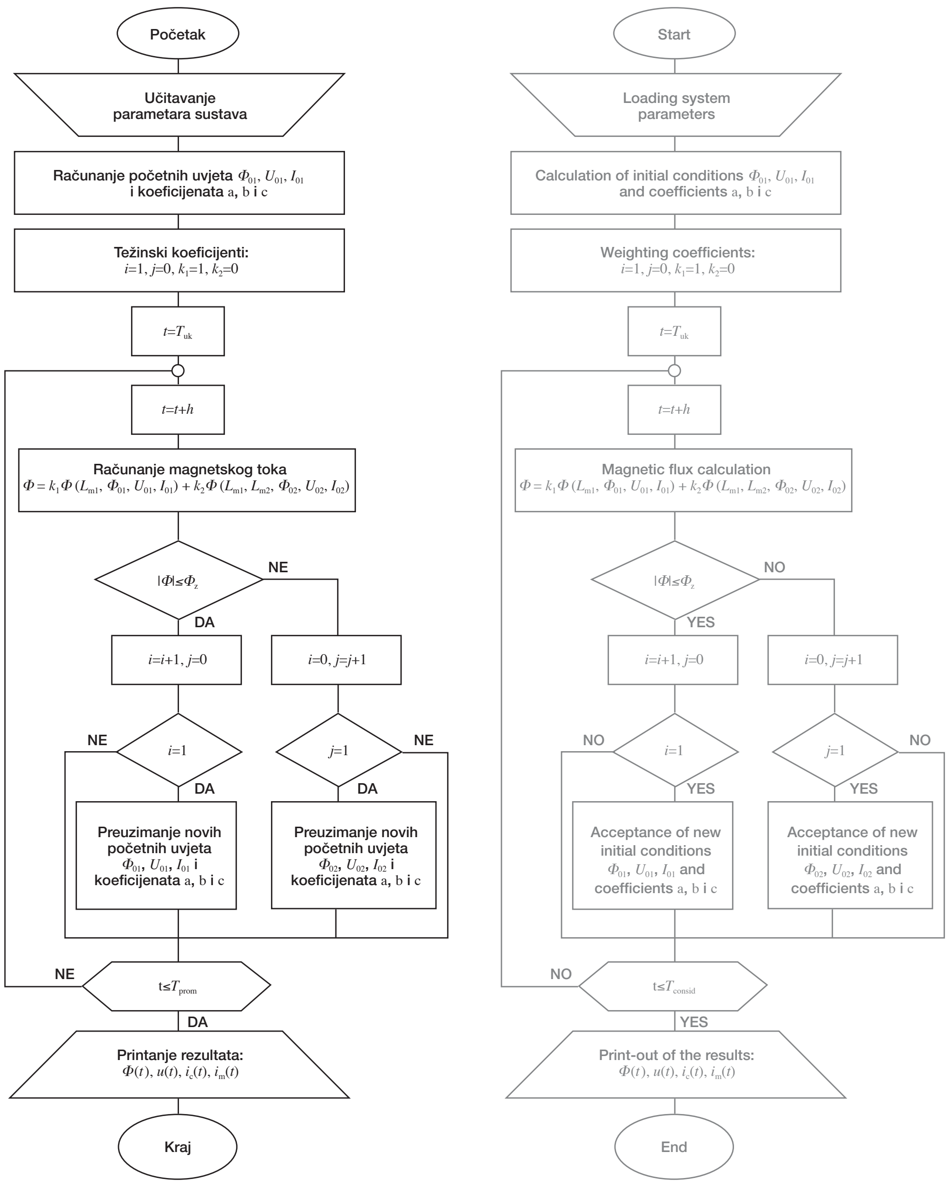
The transformer magnetizing current $i_m$ is determined on the basis of equations (3) and (4).

It is generally possible to develop an algorithm that would solve differential equations (5) and (6) by following the value of the instantaneous magnetic flux with the corresponding initial conditions. By introducing weighting coefficients $k_1$ and $k_2$ that would assume the value of 0 or 1, it is possible to make a loop that that would constantly calculate the value of the magnetic flux in the saturated and unsaturated regions, taking the corresponding initial conditions into account.

Transformer remnant magnetism, $\Phi_{rem}$ can be taken into account if this value is entered into the calculation $\Phi(T_{uk}) = \Phi_{rem}$. The hysteresis loop is ignored, which is completely acceptable in practical applications for power transformers [16].

Pojednostavljeni algoritam računanja varijabli stanja (magnetskog toka, napona i struje) dan je na slici 6. Otežavajuća činjenica pri realizaciji programa je da se početni uvjeti pri svakom prijelazu iz jednog u drugo područje stalno moraju preračunavati.

A simplified algorithm for the calculation of state variables (magnetic flux, voltage and current) is presented in Figure 6. A complicating factor in the implementation of the program is that the initial conditions at every transition from one region to another must constantly be recalculated.




**Slika 6**
Razvijeni algoritam, pojednostavljeni model
**Figure 6**
Developed algorithm, simplified model

## 4 NUMERIČKI PRISTUP

Sada će se analizirati slučaj uklapanja transformatora sa svim elementima prema slici 7. Dok se transformator još uvijek nalazi u nezasićenom području, gdje će se radi jednostavnosti induktivitet željezne jezgre označiti s $L_m$, vrijede jednadžbe:

## 4 NUMERICAL APPROACH

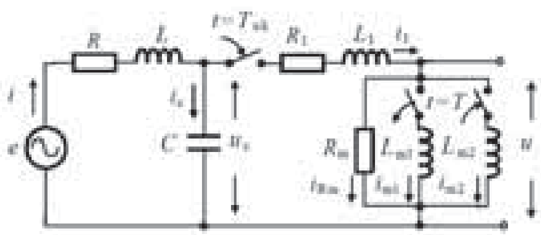
A case will now be analyzed of the energization of a transformer with all the elements according to Figure 7. While the transformer is still in the unsaturated region, where for purposes of simplicity the inductance of the iron core will be designated by $L_m$, the following equations apply:

$$e = E_m \cos\omega t = R \cdot i + L \frac{\mathrm{d}i}{\mathrm{d}t} + u_C , \tag{18}$$

$$i = i_C + i_1 = C \frac{\mathrm{d}u_C}{\mathrm{d}t} + i_1 , \tag{19}$$

$$i_1 = i_{Rm} + i_m = \frac{1}{R_m} u + \frac{1}{L_m} \Phi = \frac{1}{R_m} \frac{\mathrm{d}\Phi}{\mathrm{d}t} + \frac{1}{L_m} \Phi , \tag{20}$$

$$u_C = R_1 \cdot i_1 + L_1 \frac{\mathrm{d}i_1}{\mathrm{d}t} + u = R_1 \cdot i_1 + L_1 \frac{\mathrm{d}i_1}{\mathrm{d}t} + \frac{d\Phi}{\mathrm{d}t} . \tag{21}$$




**Slika 7**
Uklapanje transformatora – potpuni model
**Figure 7**
Transformer energization – complete model

Transformacijom posljednje četiri jednadžbe dolazimo do diferencijalne jednadžbe četvrtog reda oblika:

Through the transformation of the last four equations, we arrive at fourth-order differential equations:

$$e = a_4 \frac{\mathrm{d}^4\Phi}{\mathrm{d}t^4} + a_3 \frac{\mathrm{d}^3\Phi}{\mathrm{d}t^3} + a_2 \frac{\mathrm{d}^2\Phi}{\mathrm{d}t^2} + a_1 \frac{\mathrm{d}\Phi}{\mathrm{d}t} + a_0 \Phi , \tag{22}$$

gdje su konstante $a_i$, $i = 0, 1, 2, 3, 4$ dane sa:

where the constants $a_i$, $i = 0, 1, 2, 3, 4$ are as follows:

$$a_0 = \frac{R}{L_m} + \frac{R_1}{L_m}, \tag{22a}$$

$$a_1 = R\left(\frac{C \cdot R_1}{L_m} + \frac{1}{R_m}\right) + \frac{L}{L_m} + \frac{R_1}{R_m} + \frac{L_1}{L_m} + 1, \tag{22b}$$

$$a_2 = R \cdot C\left(\frac{R_1}{R_m} + \frac{L_1}{L_m} + 1\right) + L\left(\frac{C \cdot R_1}{L_m} + \frac{1}{R_m}\right) + \frac{L_1}{R_m}, \tag{22c}$$

$$a_3 = \frac{R \cdot C \cdot L_1}{R_m} + L \cdot C\left(\frac{R_1}{R_m} + \frac{L_1}{L_m} + 1\right), \tag{22d}$$

$$a_4 = \frac{L \cdot C \cdot L_1}{R_m}. \tag{22e}$$

Uz realne podatke [8]:

- $E_m$ = 172 kV,
- $R$ = 8,82 $\Omega$,
- $L$ = 0,281 H,
- $C$ = 4,218 $\mu$F,
- $R_1$ = 0,529 $\Omega$,
- $L_1$ = 0,126 H,
- $\Phi_z$ = 657,88 W,
- $L_{m1}$ = 185,24 H,
- $L_{m2}$ = 0,253 H,
- $R_m$ = 0,576 $\cdot 10^6$ $\Omega$,

primjenjujući Bairstow numeričku metodu, za korjene karakteristične jednadžbe bi dobili rješenja:

with real data [8]:

- $E_m$ = 172 kV,
- $R$ = 8,82 $\Omega$,
- $L$ = 0,281 H,
- $C$ = 4,218 $\mu$F,
- $R_1$ = 0,529 $\Omega$,
- $L_1$ = 0,126 H,
- $\Phi_z$ = 657,88 W,
- $L_{m1}$ = 185,24 H,
- $L_{m2}$ = 0,253 H,
- $R_m$ = 0,576 $\cdot 10^6$ $\Omega$,

and by applying the Bairstow numerical method, the roots of the characteristic equation are obtained as follows:

$$p_1 = -4{,}575 \cdot 10^6 = -\alpha, \tag{23}$$

$$p_2 = -0{,}0504 = -\beta, \tag{24}$$

$$p_{3,4} = -15{,}876 \pm \mathrm{j}919{,}096 = -\gamma \pm \mathrm{j}\omega_0. \tag{25}$$

Tada je opće rješenje jednadžbe (22):

Then the general solution of the equation (22) is:

$$\Phi(t) = a\cdot e^{-\alpha t} + b\cdot e^{-\beta t} + e^{-\gamma t}\left(c\cdot\cos\omega_0 t + d\cdot\sin\omega_0 t\right) + B\cdot\sin\left(\omega t + \Psi\right). \tag{26}$$

Očita je jaka rasutost korijena $p_1$ i $p_2$. Kada bi po analogiji na razmatranje kao u poglavlju 3 formirali matrice $\boldsymbol{M}$, $\boldsymbol{K}$ i $\boldsymbol{N}$, lako bismo zaključili da matrica $\boldsymbol{K}$ predstavlja singularnu matricu, jer u prvom stupcu sadrži umnoške broja $e^{p_1 T_{uk}}$. Svi ti brojevi su za računalo praktički jednaki nuli zbog goleme vrijednosti $p_1$. Dakle, klasičan analitički pristup u općem se slučaju ne bi mogao provesti zbog singularnosti matrice $\boldsymbol{K}$. U daljem dijelu razmatrat će se numerički pristup rješavanja ovog problema. Međutim, i pri numeričkom pristupu veoma je važno obratiti pozornost na izbor odgovarajućeg numeričkog postupka zbog istaknute činjenice da su korijeni karakteristične jednadžbe jako rasuti u lijevom dijelu kompleksne ravnine. Jaka disperzija korijena karakteristične jednadžbe definira zasebnu klasu diferencijalnih jednadžbi poznatih pod imenom krute diferencijalne jednadžbe (*stiff differential equations*). Naime, diskutabilna je apsolutna stabilnost numeričkih postupaka primijenjenih na ovu vrstu jednadžbi [17]. Nijedan od klasičnih numeričkih postupaka u eksplicitnoj formi, bio jednokoračni ili višekoračni tipa Eulera, Runge-Kuta, Adams-Moulton itd. pri standardnim koracima integracije, ne osigurava apsolutnu stabilnost postupka, što dovodi do divergiranja rješenja u numeričkom smislu (pogreška $\delta_k$ u $k$-toj iteraciji izaziva u $k$+1-oj iteraciji pogrešku $\delta_{k+1} > \delta_k$). Apsolutnu stabilnost osiguravaju jedino implicitni numerički postupci [17] i [18], mada i pri njihovoj upotrebi treba biti jako oprezan. U konkretnom primjeru upotrijebljeno je apsolutno stabilno implicitno trapezno pravilo.

High dispersion of the roots $p_1$ and $p_2$ is evident. If matrices $\boldsymbol{M}$, $\boldsymbol{K}$ and $\boldsymbol{N}$ are formed, analogically to the discussion in Chapter 3, it could be easily concluded that matrix $\boldsymbol{K}$ represents a singular matrix because it contains multiples of the number $e\, p_1 T_{uk}$ in the first column. All these numbers are practically equal to zero for a computer due to the enormous value of $p_1$. Therefore, the classical analytical approach in a general case could not be implemented due to the singularity of matrix $\boldsymbol{K}$. The numerical approach to the solution of this problem will be discussed subsequently. However, with the numerical approach it is very important to pay attention to the selection of the suitable numerical approach procedure due to the significant fact that the roots of the characteristic equation are highly dispersed in the left part of the complex plain. The high root dispersion of the characteristic equation defines a separate class of differential equations known as stiff differential equations. The absolute stability of the numerical approaches applied in this type of equation is disputable [17]. None of the classical numerical approaches in explicit form, whether of the single-step or multistep Euler, Runge-Kutta, Adams-Moulton type etc. using standard integration steps, assures the absolute stability of the procedure, which leads to divergence of the solutions in the numerical sense (error $\delta_k$ in the $k$-*th* iteration causes error $\delta_{k+1} > \delta_k$ in the $k$+1 iteration). Only implicit numerical procedures guarantee absolute stability [17] and [18], although it is necessary to use them very cautiously. In a concrete example, the absolutely stable implicit trapezoidal rule is applied.

Jednadžbe (18) do (22) će se napisati u prostoru stanja uzimajući da je vektor varijabli stanja:

Equations (18) to (22) can be written in the state space form where the state variable vector is:

$$\boldsymbol{x} = \begin{bmatrix} i & u_C & i_1 & \Phi \end{bmatrix}^T. \tag{27}$$

Za nezasićeno područje gdje inače vrijedi:

For the unsaturated region where the following otherwise applies:

$$i_m = \frac{1}{L_{m1}}\Phi \quad \text{za / for} \quad |\Phi| \le \Phi_z, \tag{28}$$

dobiva se jednadžba u prostoru stanja:

the following state space equation is obtained:

$$\dot{x} = A_1 x + b_1, \tag{29}$$

gdje su:

Where:

$$A_1 = \begin{bmatrix} -\frac{R}{L} & -\frac{1}{L} & 0 & 0 \\ \frac{1}{C} & 0 & -\frac{1}{C} & 0 \\ 0 & \frac{1}{L_1} & -\left(\frac{R_1}{L_1} + \frac{R_m}{L_1}\right) & \frac{R_m}{L_1 L_{m1}} \\ 0 & 0 & R_m & -\frac{R_m}{L_{m1}} \end{bmatrix}, \tag{29a}$$

$$b_1 = \left[\frac{1}{L} E_m \cos \omega t \;\; 0 \;\; 0 \;\; 0\right]^T. \tag{29b}$$

U zasićenom području gdje inače vrijedi relacija:

In the saturated region where the following relation otherwise applies:

$$i_m = \frac{1}{L_{m2}} \Phi + \operatorname{sign}(\Phi) \left(\frac{1}{L_{m1}} - \frac{1}{L_{m2}}\right) \Phi_z \quad \text{za / for} \quad |\Phi| > \Phi_z, \tag{30}$$

dobiva se:

the following is obtained:

$$\dot{x} = A_2 x + b_2, \tag{31}$$

gdje su:

where:

$$A_2=\begin{bmatrix} -\frac{R}{L} & -\frac{1}{L} & 0 & 0 \\ \frac{1}{C} & 0 & -\frac{1}{C} & 0 \\ 0 & \frac{1}{L_1} & -\left(\frac{R_1}{L_1}+\frac{R_m}{L_1}\right) & \frac{R_m}{L_1 L_{m2}} \\ 0 & 0 & R_m & -\frac{R_m}{L_{m2}} \end{bmatrix}, \tag{31a}$$

$$b_2=\left[\frac{1}{L}E_m\cos\omega t \;\; 0 \;\; \frac{R_m}{L_1}\operatorname{sign}(\Phi)\left(\frac{1}{L_{m1}}-\frac{1}{L_{m2}}\right)\Phi_z - R_m\operatorname{sign}(\Phi)\left(\frac{1}{L_{m1}}-\frac{1}{L_{m2}}\right)\Phi_z\right]^T. \tag{31b}$$

Implicitno trapezno pravilo primijenjeno na sustav $\dot{x}=\boldsymbol{A}_i x+bi,\;\; i=1,2$ daje iteracijsku vezu:

The implicit trapezoidal rule applied to the system $\dot{x}=\boldsymbol{A}_i x+bi,\;\; i=1,2$ yields the iteration expression:

$$x_{k+1}=\left[E-\frac{h}{2}A_i\right]^{-1}\left(\left[E+\frac{h}{2}A_i\right]x_k+\frac{h}{2}\left[b_i(t_k)+b_i(t_{k+1})\right]\right) \tag{32}$$

U posljednjoj relaciji sa $h$ označen je korak integracije i on je veoma problematičan za eksplicitne metode. Naime, da bi se osigurala stabilnost ovih postupaka korak se mora održati dovoljno malim da bi testovi stabilnosti bili zadovoljeni. Za Eulerovo pravilo je potrebno da korak integracije bude

In the previous expression, $h$ is designated as the integration step and it is highly problematic for explicit methods. In order to assure the stability of these procedures, the step should be kept sufficiently small in order to satisfy the stability tests. For Euler's rule, it is necessary for the integration step to be:

$$h\le\min_i\left\{\frac{2\operatorname{Re}(\lambda_i)}{|\lambda_i|^2}\right\}, \tag{33}$$

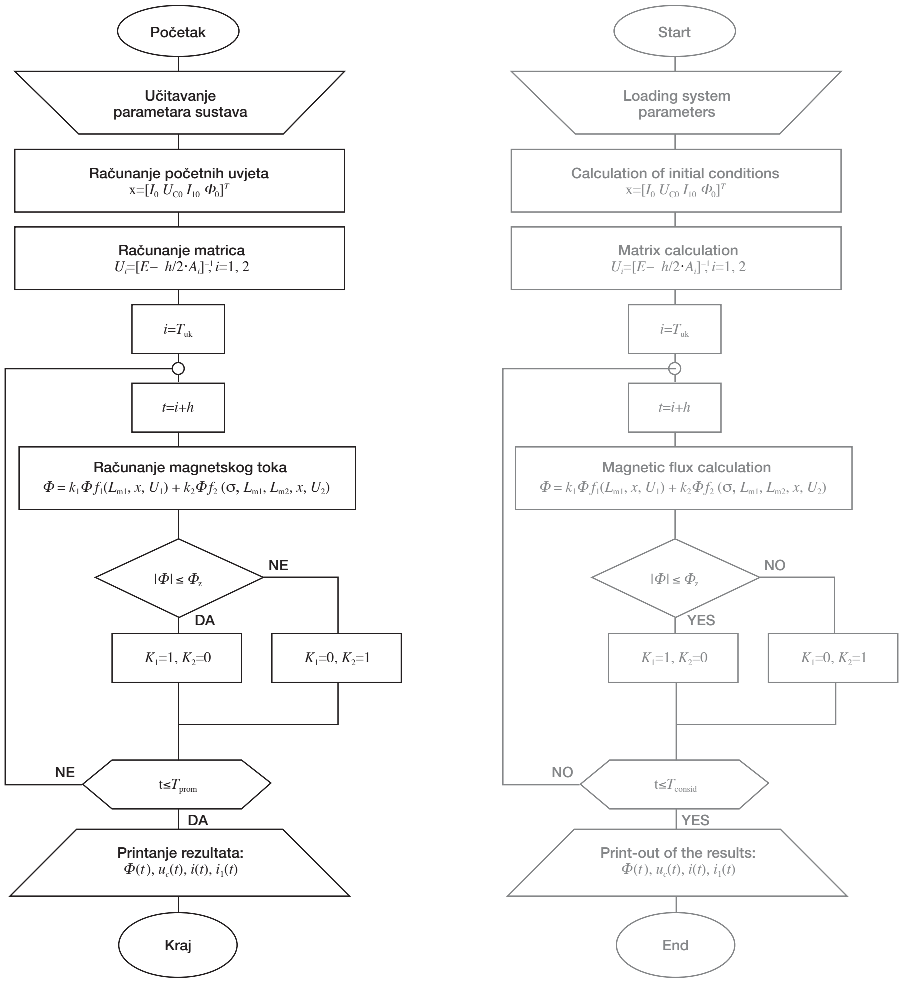
gdje su sa $\lambda_i$ označene sve svojstvene vrijednosti matrice $\boldsymbol{A}_i$. Za ovaj bi primjer već za nezasićeno područje korak bio:

where $\lambda_i$ denotes all the characteristic values of matrix $\boldsymbol{A}_i$. For this example, the step for the unsaturated region would be:

$$h\le\frac{2\cdot 4{,}575\cdot 10^6}{4{,}575^2\cdot 10^{12}}=4{,}37\cdot 10^{-7}. \tag{34}$$

Pri upotrebi implicitnog trapeznog pravila nije potrebno voditi računa o veličini koraka $h$.
Dakle, moguće je načiniti algoritam, slika 8, koji će prema (32) numerički rješavati sustav diferencijalnih jednadžbi (29) za $|\Phi|\le\Phi_z$ i (31) za $|\Phi|>\Phi_z$.

When applying the implicit trapezoidal rule, it is not necessary to take the size of step $h$ into account. Therefore, it is possible to develop an algorithm, Figure 8 , which according to (32) will numerically solve the system of differential equations (29) for $|\Phi|\le\Phi_z$ and (31) for $|\Phi|>\Phi_z$.




**Slika 8**
Razvijeni algoritam, potpuni model
**Figure 8**
Developed algorithm, complete model

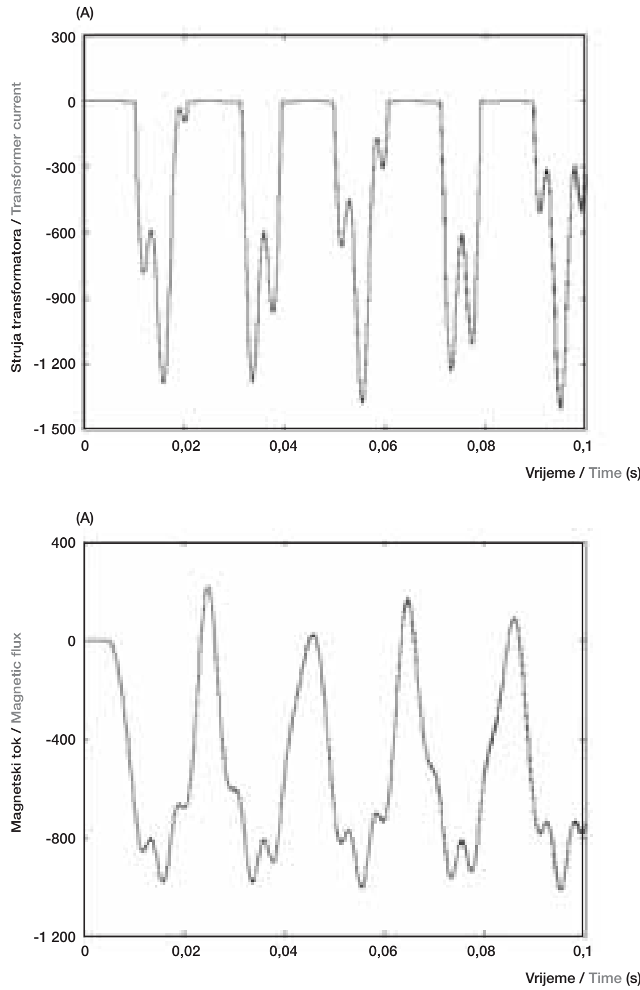
## 5 TEST PRIMJER

Programi dobiveni prema algoritmima sa slika 6 i 8 testirani su na MATLAB/Simulink/Power System Blockset (PSB), dio MATLAB-a za elektromagnetske tranzijente [19]. Parametri modela preuzeti su iz [8]. Rezultati simulacija dani su na slikama 9 i 10.

## 5 TEST EXAMPLE

The programs obtained according to the algorithms from Figures 6 and 8 have been tested using the MATLAB/Simulink/Power System Blockset (PSB), a part of MATLAB for electromagnetic transients [19]. The model parameters were taken from [8]. The simulation results are presented in Figures 9 and 10.

**Slika 9**
Pojednostavljeni model, $T_{uk} = 5$ ms, $\Phi_{rem} = 0$
**Figure 9**
Simplified model, $T_{uk} = 5$ ms, $\Phi_{rem} = 0$




Slika 9 pokazuje rezultate razvijenog algoritma koji uzima u obzir pojednostavljeni model uklapanja transformatora, bez prigušnih elemenata, poglavlje 3.

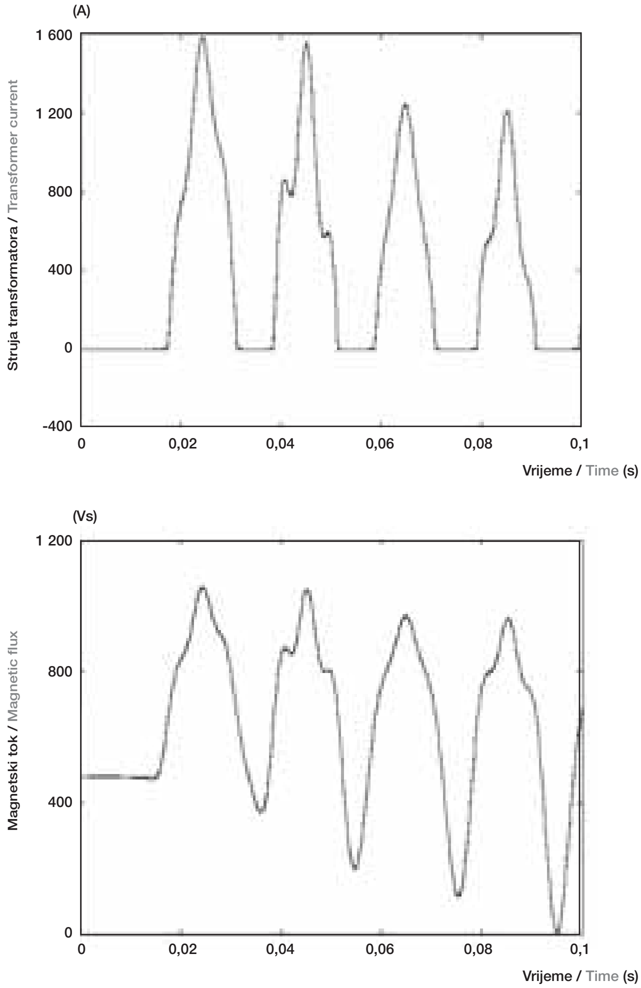
Slika 10 pokazuje rezultate razvijenog algoritma koji uzima u obzir potpuni model uklapanja transformatora, sa svim elementima, poglavlje 4. Na slici 10 je uvažen i remanentni magnetizam transformatora.

Može se zaključiti da se rezultati realiziranih programa u potpunosti podudaraju s programom PSB.

Figure 9 presents the results of the developed algorithm that takes the simplified model of transformer energization into account, without the damping elements, Chapter 3.

Figure 10 presents the results of the developed algorithm that takes the complete model of transformer energization into account, with all the elements, Chapter 4. In Figure 10, the transformer remnant magnetism has also been taken into account.

It can be concluded that the results of the realized programs are in complete agreement with the PSB program.




**Slika 10**
Potpuni model,
$T_{uk}$ = 15 ms,
$\Phi_{rem}$ = 0,8 $\Phi_{nom}$
**Figure 10**
Complete model,
$T_{uk}$ = 15 ms,
$\Phi_{rem}$ = 0,8 $\Phi_{nom}$

## 6 KOMPARACIJA S MJERENJIMA

Razvijeni program se može dalje generalizirati na modeliranje trofaznih transformatora, gdje su krivulje magnetiziranja predstavljene preko konačnog broja pravaca. Tada se vrijednosti struja magnetiziranja, po fazama, računaju iz formule [20]:

## 6 COMPARISON WITH MEASUREMENTS

A developed program can be further generalized for the modeling of three-phase transformers, where the magnetizing curves are represented by a finite number of straight lines. The values of the magnetizing current, according to phases, are then calculated from the following formula [20]:

$$i_{m(j)_k} = \frac{\Phi_{(j)}}{L_{m(j)_k}} - \mathrm{sign}(\Phi_{(j)}) \sum_{i=1}^{k-1} \Phi_{zi(j)} \left( \frac{1}{L_{m(j)_i}} - \frac{1}{L_{m(j)_{i+1}}} \right). \tag{35}$$

U posljednjoj relaciji su krivulje magnetiziranja, po fazama, dane s vektorima:

In the previous expression, the magnetizing curves, according to phases, are represented by vectors:

$$L_{m(j)} = \left[L_{m(j)_1}, L_{m(j)_2}, \dots, L_{m(j)_N}\right]^T, \tag{36}$$

$$\Phi_{z(j)} = \left[\Phi_{z(j)_1}, \Phi_{z(j)_2}, \dots, \Phi_{z(j)_N}\right]^T, \tag{37}$$

gdje su:

$j$ = 1, 2, 3 oznake faza,
$N$ = ukupni broj pravaca krivulje magnetiziranja.

Razvijeni algoritam je verificiran kompariranjem izmjerenih i simuliranih struja uklapanja neopterećenog trofaznog transformatora. Parametri trofaznog, trostupnog 2,4 kVA, 0,38/0,5 kV, Y-Y transformatora su:

– napon kratkog spoja $u_{k\%}$ = 3 %,
– djelatni otpor namota po fazi $R_{tr}$ = 1,5 Ω,
– rasipni induktivitet $L_{tr}$ = 1 mH,
– gubici u jezgri transformatora $R_m$ = 4 626 Ω.

Nelinearna krivulja magnetiziranja je predstavljena preko 13 pravaca, [20]. Pri modeliranju trostupnog transformatora uvažena je i nulta reaktancija $L_0$ = 15 mH [20].

Model transformatora [20], s pridodanom nultom reaktancijom prikazan je na slici 11.

where:

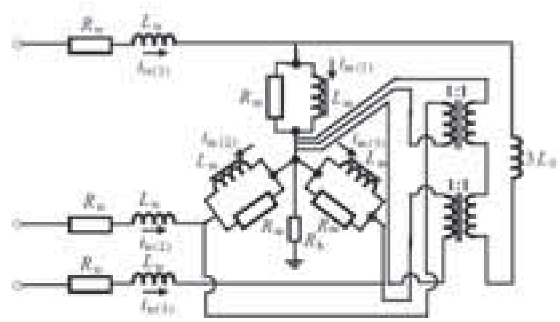
$j$ = 1, 2, 3 are phase designations,
$N$ = the total number of straight lines of the magnetizing curve.

The developed algorithm is verified by compairson between the measured and simulated inrush currents of the no-load three-phase transformer. The parameters of the three-phase three-legged 2,4 kVA, 0,38/0,5 kV, Y-Y transformer are as follows:

– short-circuit voltage $u_{k\%}$ = 3 %,
– effective resistance per winding phase $R_{tr}$ = 1,5 Ω,
– leakage inductance $L_{tr}$ = 1 mH,
– iron core losses $R_m$ = 4 626 Ω.

A nonlinear magnetizing curve is presented via 13 straight lines [20]. In the modeling of a three-legged transformer, zero reactance $L_0$ = 15 mH is taken into account [20].

A transformer model [20] with added zero reactance is presented in Figure 11.



**Slika 11**
Model trofaznog, trostupnog transformatora s pridodanom nultom reaktancijom
**Figure 11**
Model of a three-phase, three-legged transformer with added zero reactance

Izvor je modeliran s vektorom elektromotorne sile po fazama:

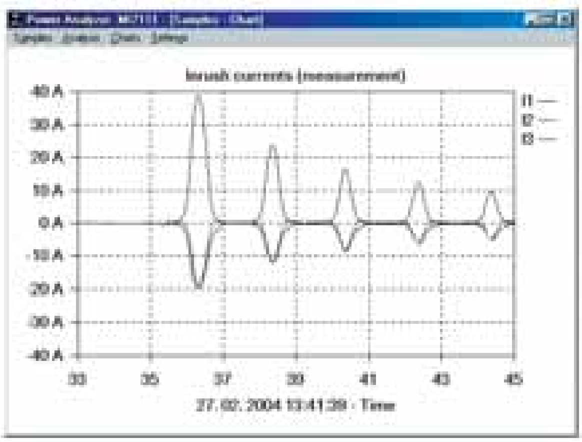
The source is modeled with a vector of the electromotive force for each phase:

$$E = \left[311\cos(\omega t - 34^{\circ}),\ 311\cos(\omega t + 86^{\circ}),\ 311\cos(\omega t + 206^{\circ})\right]^{T}. \tag{38}$$

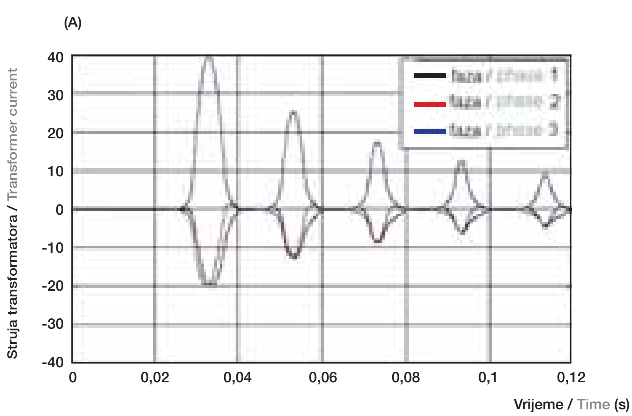
Rezultati mjerenja i simulacija dani su na slici 12.

The measurement and simulation results are presented in Figure 12.

a) Mjerenje / Measurement




b) Simulacija / Simulation




**Slika 12**
Struje uklapanja trofaznog transformatora: mjerenje i simulacija
**Figure 12**
Inrush current of a three-phase transformer: measurement and simulation

Analizom rezultata mjerenja i simulacija dolazi se do zaključka da maksimalna relativna pogreška, računata po tjemenim vrijednostima struje uklapanja tijekom svakog perioda, iznosi 3,56 %.

Through analysis of the measurement and simulation results, the conclusion is reached that the maximum relative error calculated according to the peak inrush current values during each period amounts to 3,56 %.

## 7 ZAKLJUČAK

U radu je opisan model transformatora primjenjiv u prijelaznim pojavama relativno niskih frekvencija. Za energetske transformatore velikih snaga pokazano je da se krivulja magnetiziranja kvalitativno može predstaviti preko dva pravca. Pokazane su granice upotrebe analitičkih metoda proračuna prijelaznih pojava u transformatorima. Za numeričko rješavanje sustava krutih diferencijalnih jednadžbi iskorišteno je implicitno trapezno pravilo. Razvijeni algoritam je moguće aplicirati u niskofrekvencijskim prijelaznim pojavama kao što su: uklapanje transformatora, ferorezonancija, ispad tereta, kvarovi transformatora itd. Na kraju je pokazan primjer upotrebe realiziranog algoritma na proračun prijelazne pojave uklapanja trofaznog trostupnog transformatora. Kompariranjem mjerenih i simuliranih struja uklapanja trofaznog transformatora ustanovljeno je da se pogreške nalaze u zadovoljavajućim granicama (maksimalno 3,56 %).

## 7 CONCLUSION

A transformer model applicable to relatively low frequency transient phenomena is described in the article. For power transformers with high power ratings, it was demonstrated that the magnetizing curve can be adequately presented with two straight lines. The limits for the use of analytical methods for the calculation of transient phenomena in transformers are presented. The implicit trapezoidal rule was used for the numerical solution of a system of stiff differential equations. The developed algorithm can be applied to low frequency transient phenomena such as transformer energization, ferroresonance, load switch-off, transformer faults etc. An example of the application of the developed algorithm was presented for the calculation of the transients that occur during the energization of a three-phase, three-legged transformer. Through comparison of the measured and simulated inrush currents of the three-phase transformer, it was established that the errors were within acceptable limits (a maximum of 3,56 %).

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Uredništvo primilo rukopis:
2007-07-10

Prihvaćeno:
2007-07-29

Manuscript received on:
2007-07-10

Accepted on:
2007-07-29

# DIJAGNOSTIČKI PREGLED RASPADA ELEKTROENERGETSKOG SUSTAVA NA OTOKU RODOSU

# DIAGNOSTIC REVIEW OF A BLACKOUT IN RHODES

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U radu se daje tehnička analiza jednog incidenta koji se dogodio 21. ožujka 2007. godine u 00:50 sati u noći i doveo do dvosatnog potpunog raspada elektroenergetskog sustava na otoku Rodosu. Analiza događanja temelji se na registriranim operativnim podacima kao i nalazima na terenu. Izvršena je tehnička analiza smetnji kako bi se utvrdili vjerojatni uzroci i čimbenici koji su pridonijeli pojavi smetnji. S obzirom da se radi o izoliranom sustavu koji je osobito je osjetljiv na poremećaje, ispitane su uloge zaštite sustava kao i kolebanja proizvodnje vjetroelektrana tijekom incidenta. Izvučeni su zaključci od praktičnog značenja i dane su preporuke korektivnih mjera koje valja provesti kako bi se u budućnosti spriječile takve smetnje.

A technical review of an incident on March 21, 2007 that began at 00:50 a.m. and led to a two-hour blackout of the island of Rhodes electric power system is presented with the complete sequence, including all the relevant registered operational data as well as the on-site field findings. A technical analysis of the disturbance was performed to determine the probable causes and factors that contributed to the duration of the disturbance. Since the system is an isolated one, it is particularly vulnerable to perturbations. The roles of system protection and wind power generation during the incident are examined. Conclusions of practical importance are drawn, including recommendations for corrective measures to be implemented for preventing disturbances of this kind from reoccurring in the future.

Ključne riječi: izolirani elektroenergetski sustav, nestanak struje
Key words: blackout, isolated electric power system

# 1 UVOD

Izolirani otočni elektroenergetski sustavi zanimljivi su s tehničkog stajališta jer pokazuju neke izrazite značajke. Ako je u takvim sustavima prisutan i visok stupanj proizvodnje vjetroelektrana, javlja se u određenim okolnostima veća osjetljivost na pogonske poremećaje.

Elektroenergetski sustav grčkog otoka Rodosa izolirani je sustav s ukupno 234 MW instaliranog kapaciteta termoelektrana (5 dizelskih, 2 parne i 4 plinske turbine) te 15 MW instalirane snage u vjetroelektranama. Međutim, zbog nekih tehničkih problema i karakteristika termoelektrana, stvarna snaga termoelektrana iznosi tek približno 192 MW. Godine 2006. proizvodnja u satu vršnog opterećenja iznosila je 192,6 MWh. To znači da sustav nije uvijek imao na raspolaganju rezervnu snagu.

U ovom se članku istražuje incident poremećaja sustava 21. ožujka 2007. godine koji je započeo u 00:50 sati u noći i doveo do dvosatnog raspada elektroenergetskog sustava na otoku Rodosu.

U vrijeme neposredno prije incidenta u pogonu su bili dva parna bloka (ATM 1 i ATM 2), svaki opterećen s 10 MW (rotirajuća rezerva svakog agregata 2 MW), dva dizelska bloka (D1 i D3): s opterećenjem 6 MW (rotirajuća rezerva 5 MW), ostala proizvodnja s 12 MW (rotirajuća rezerva 5 MW) te 12 MW vjetroelektrana. Vremenski uvjeti bili su loši i jamačno su odigrali određenu ulogu na početku incidenta. Na slici 1 dana je jednopolna shema sustava.

Smetnje u sustavu započele su asimetričnim trofaznim kratkim spojem bez zemljospoja. Taj je kvar uspješno uklonjen. Međutim, zbog nestabilnosti uzrokovane zaštitnim mehanizmima sustav se nije oporavio već je postupno gubio proizvodnju i izazivao značajnu redukciju opterećenja što je, nakon 2 minute i 45 sekundi od uklanjanja prvog kvara, konačno dovelo do potpunog raspada elektroenergetskog sustava.

# 1 INTRODUCTION

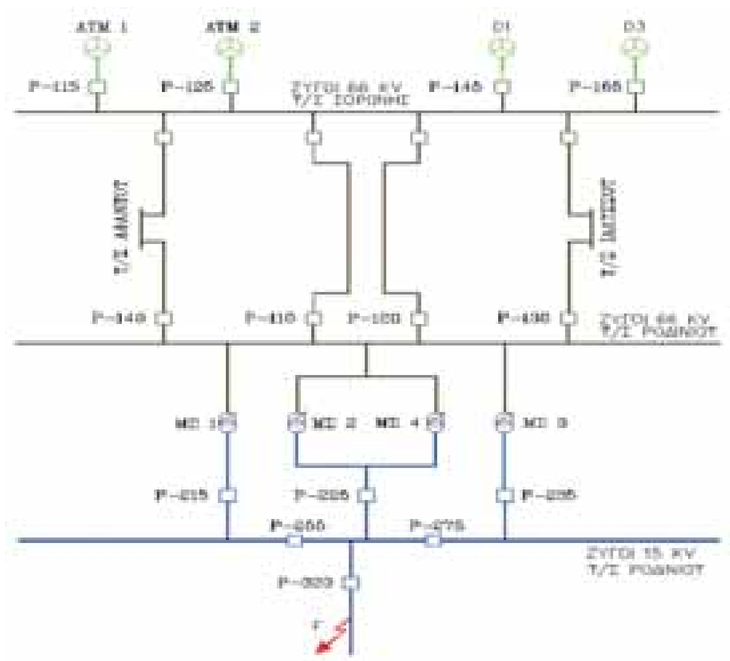
Isolated island power systems are of interest from the technical point of view because they exhibit notable characteristics. For example, when there is a high penetration of wind generation, there is greater vulnerability to operation perturbations under certain conditions.

The electric power system of the Greek island of Rhodes is an isolated system with 234 MW installed capacity of thermal plants (5 diesel, 2 steam and 4 gas turbines) plus 15 MW wind generation. However, due to some technical problems and the characteristics of the thermal generating plant, the actual thermal generation capacity is only about 192 MW. In the year 2006, the mean average hourly generation peaked at 192,6 MWh. This means that the system did not have appreciable reserve power at all times.

This article examines the system disturbance incident of March 21, 2007 that began at 00:50 a.m. and led to a two-hour blackout of the Rhodes Island Electrical Power System.

At the time just before the incident, the system was operating with 2 steam units (ATM 1, and ATM 2) with 10 MW production each (a spinning reserve of 2 MW each) and 2 diesel units (D1, and D3): one producing 6 MW (with a 5 MW spinning reserve) and the other generating 12 MW (with a 5 MW spinning reserve). At the same time, wind generation was 12 MW. A one-line diagram of the system is shown in Figure 1. The weather conditions were severe and played a definite role at the start of the incident.

The system disturbance began with an asymmetrical three-phase fault, not involving ground. This fault was successfully cleared. However, due to instabilities triggered by the protective mechanisms, the system never really recovered, gradually losing generation and causing significant load shedding, which finally led to a complete blackout lasting 2 minutes and 45 seconds after the initial fault had been cleared.




**Slika 1**
Jednopolna shema sustava na početku smetnje
**Figure 1**
One-line diagram of the system at the start of the fault

Kvar se dogodio na trafostanici Rhodini na distribucijskom vodu napajanom putem prekidača P-320 od 15 kV sabirnice, kako je prikazano na slici 1. Nakon gubljenja struje iz voda aktivirana je zaštita i otpušteni su prekidači P-320, P-255 i P-225. Zbog kvara je izgorio drveni stup distribucijskog voda te se kasnije morao zamijeniti. Vrijeme je bilo vrlo loše u trenutku kvara, pri čemu je jak vjetar raspršivao kapljice morske vode po izolatorima vodova, što je intenziviralo površinsko pražnjenje. Naknadnom analizom pronađen je srednji fazni vodič (u vodoravnom rasporedu od 3 faza) prekinut na jednom drvenom stupu. Isto se dogodilo s drugim stupom istog voda gdje su, osim prekinutog srednjeg vodiča, također bili razbijeni porculanski izolatori, najvjerojatnije kao posljedica struje zemljospoja. Taj je početni kvar konačno uklonjen oko 13 sekundi nakon što se dogodio. Međutim, 19 sekundi nakon uklanjanja kvara ispao je parni blok #1 a potom, 2 minute i 45 sekundi nakon uklanjanja kvara, i parni blok #2, što je rezultiralo raspadom elektroenergetskog sustava.

The fault occurred at the Rhodini substation on the distribution line fed through the breaker P-320 from the 15 kV bus, as shown in Figure 1. Following the fault, protection was activated and tripped the breakers P-320, P-255 and P-225. As a result of the fault, a wooden pole of the distribution line burned and had to be replaced later. The weather was severe at the time of the fault, with strong wind spraying sea water droplets over the line insulators, thereby increasing the likelihood of a flashover. Post-mortem examination found the jumper wire for the middle phase conductor (in a horizontal arrangement of the 3 phases) cut at another wooden pole of the same distribution line. The same thing also happened to another pole of the same line where, in addition to a broken middle jumper wire, its porcelain insulators were also broken. This would most likely imply that these were the results of the fault current. This initial fault was finally cleared at about 13 sec after it happened. However, 19 sec after the fault clearance, Steam Unit #1 was lost, and 2 min and 45 sec after the fault clearance Steam Unit #2 was lost, resulting in the blackout.

## 2 ANALIZA INCIDENTA

Kako sustavu SCADA u kontrolnom centru nedostaju neke važne funkcije bilo je moguće tek samo bilježenje pogonskih podataka u realnom vremenu, dok se u mnogim slučajevima događaju značajna zakašnjenja u bilježenju podataka. Iz ispitivanja zabilježenih događaja i podataka moguće je zaključiti kako je smetnja započela asimetričnim trofaznim kratkim spojem bez zemljospoja. Ovaj zaključak temelji se na vremenskim krivuljama izmjenične struje zabilježenih digitalnim relejima prekidača P-225 i P-255 (slika 2), koji su pokazivali nepostojanje struje zemljospoja. Moglo se također zamijetiti da impendancije kvara variraju s vremenom, upućujući na električno iskrenje kao uzrok. Oscilogrami 1 i 2 (slike 3 i 4) prikazuju napone na sabirnicama 66 kV na trafostanici Rhodini, odnosno struje na prekidaču 66 kV P-110 onako kako su se i razvijali. Naknadni vremenski oscilogrami 3 i 4 (slike 5 i 6) tu oscilaciju (frekvencije 100 Hz) jasnije prikazuju. Oscilacija se održava do kraja (kao što je razvidno iz oscilograma 5 (slika 7). To može značiti i da je automatskim regulatorima napona (AVR) potrebno podešavanje.

Iz oscilograma napona moguće je izračunati veličinu napona kao funkciju vremena, i to od nastanka kvara do potpunog pada napona, kako je prikazano na slici 8.

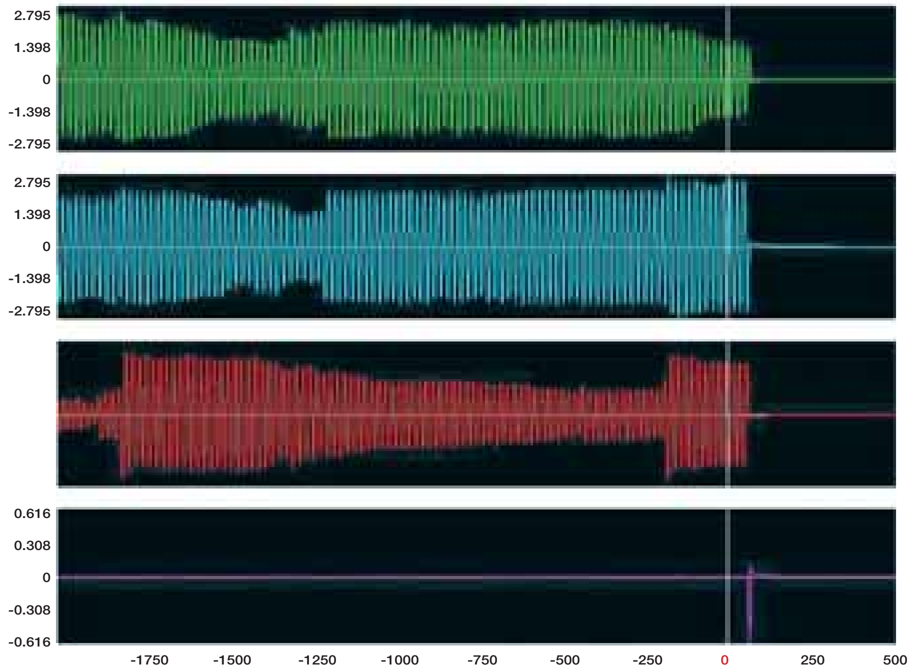
Tijekom smetnje zabilježene su promjene frekvencije širokog raspona. Relevantni podaci prikazani su na slici 9 na kojoj je vidljiva minimalna frekvencija od 47,7 Hz (2 s nakon početka smetnje) i maksimalna frekvencija od 54 Hz (16 s nakon početka smetnje).

## 2 INCIDENT ANALYSIS

At the outset, one should note that the SCADA at the Control Center leaves important functionalities to be desired. As a result, real-time registration of operation is only partially possible, while in many cases significant time delays occur in data registration. From examination of the registered events and data, one is able to see the following. The fault began as an asymmetrical three-phase fault, not involving the ground. This was evident from the time alternating current curves registered by the digital relays of the P-225 and P-255 (Figure 2) breakers, which showed zero earth current. It could also be observed that the fault impedances varied randomly with time, suggesting that the electric-arcing of varying spans was the cause. Oscillograms 1 and 2 (Figures 3 and 4) show the voltages at the 66 kV buses at Rhodini and the currents at the 66 kV breaker P-110, respectively. These oscillograms show oscillation developing as time progresses. Subsequent time Oscillograms 3 and 4 (Figures 5 and 6) show this (100 Hz frequency) oscillation more clearly. This oscillation is sustained to the end (as seen in Oscillogram 5 (Figure 7). This could indicate that the automatic voltage regulators (AVR) need adjustments.

From the voltage oscillogram, one can calculate the voltage magnitude as a function of time, from the occurrence of the fault up to the voltage collapse, as shown in Figure 8.

In the course of the disturbance, wide frequency swings were registered. The respective data are shown in Figure 9. In this figure, one can see the minimum frequency of 47,7 Hz (2 s after the start of the disturbance), and the maximum frequency of 54 Hz (16 s after the start of the disturbance).

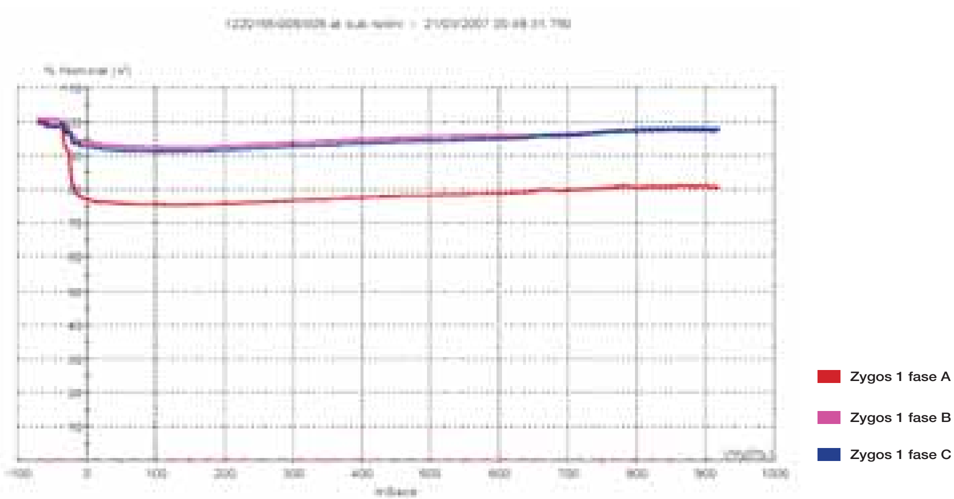



**Slika 2**
Vremenske krivulje izmjeničnih struja faza a, b, c i uzemljenja na prekidaču P-255

**Figure 2**
Time curves of the alternating currents of Phases a, b, c and ground at breaker P-255

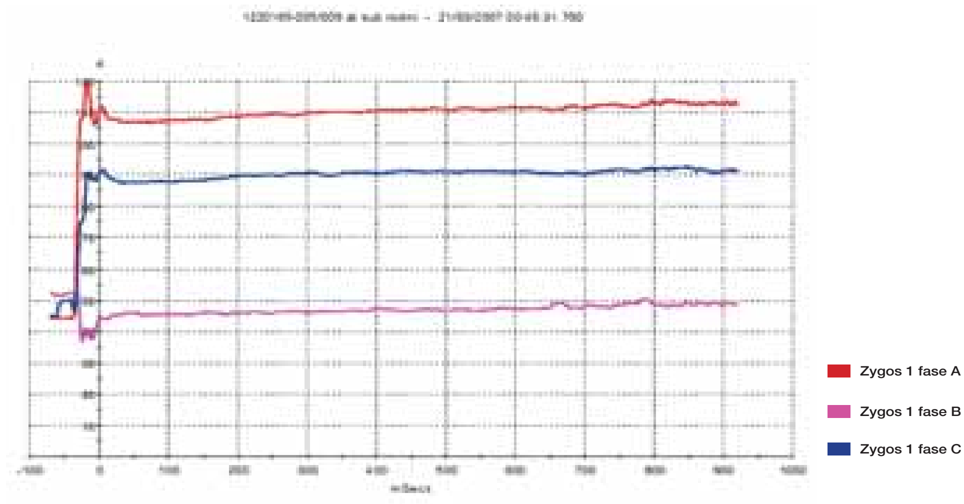
Tijekom smetnje tri su se dodatna čimbenika pokazala ključnima. Podešenja podnaponske zaštite za park vjetroelektrana kao i za pojedinačne vjetrogeneratore imala su za posljedicu ispade generatora i gubitak proizvodnje iz vjetroelektrana (24 % ukupne proizvodnje). Podešenja zaštite poduzbudnih limitera dizelskih elektrana imala su za posljedicu njihov ispad. Ispadanje 40 MW opterećenja, zbog rada automatske podfrekvencijske zaštite, rezultiralo je u preostaloj snazi od 10 MW napajanoj iz parnog bloka #2 u zadnjim trenucima neposredno prije potpunog ispada.

In the course of events, three additional factors were shown to be crucial. The under-voltage protection settings for the wind park and for the individual wind generators resulted in the loss of wind generation (24 % of the total generation). The under-excitation limiters protection settings of the diesel units resulted in the loss of those units. The shedding of 40 MW of load, due to the operation of the automatic under-frequency protection, resulted in a remaining load of 10 MW which was fed from Steam Unit #2 in the final moments just before the collapse.

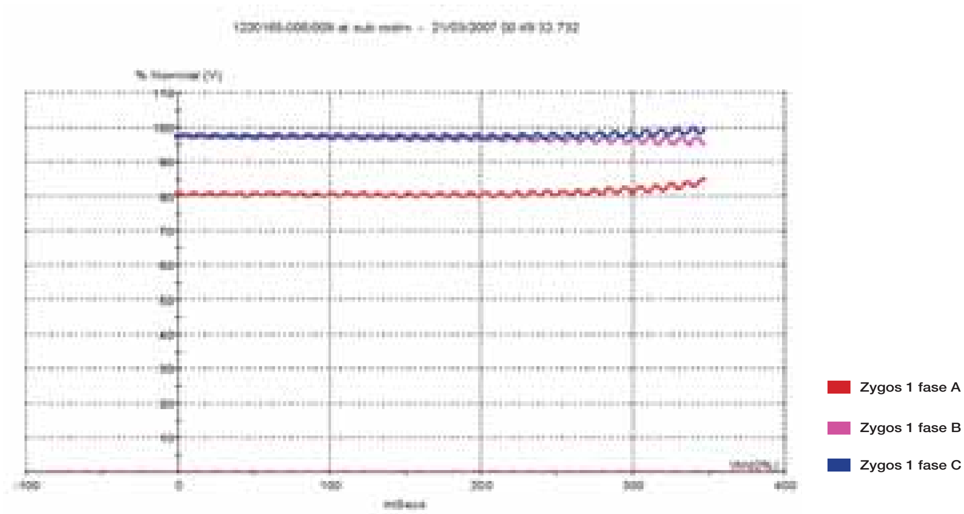



**Slika 3**
Oscilogram 1 – Naponi na sabirnici 66 kV na trafostanici Rhodini (početak gubljenja struje iz voda)

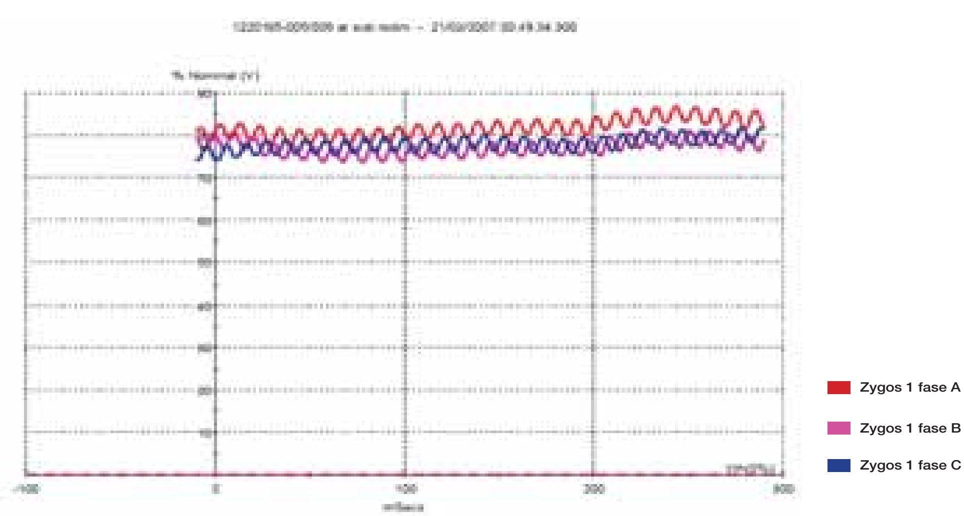
**Figure 3**
Oscillogram 1 – Voltages at the 66 kV bus at Rhodini (the fault begins)



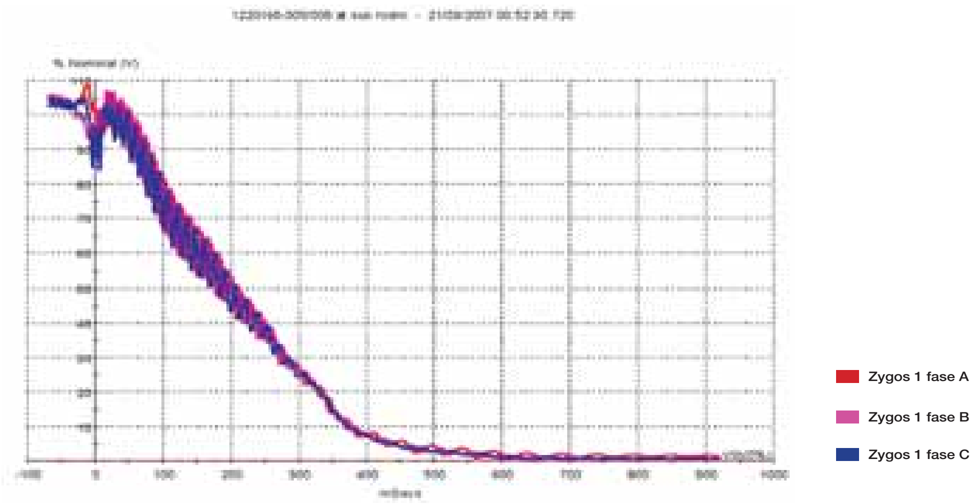

**Slika 4**
Oscilogram 2 – Struje zabilježene na prekidaču 66 kV P-110 na trafostanici Rhodini
**Figure 4**
Oscillogram 2 – Currents registered at 66 kV Breaker P-110 at Rhodini




**Slika 5**
Oscilogram 3 – Naponi na sabirnici 66 kV na trafostanici Rhodini
**Figure 5**
Oscillogram 3 – Voltages at 66 kV bus at Rhodini

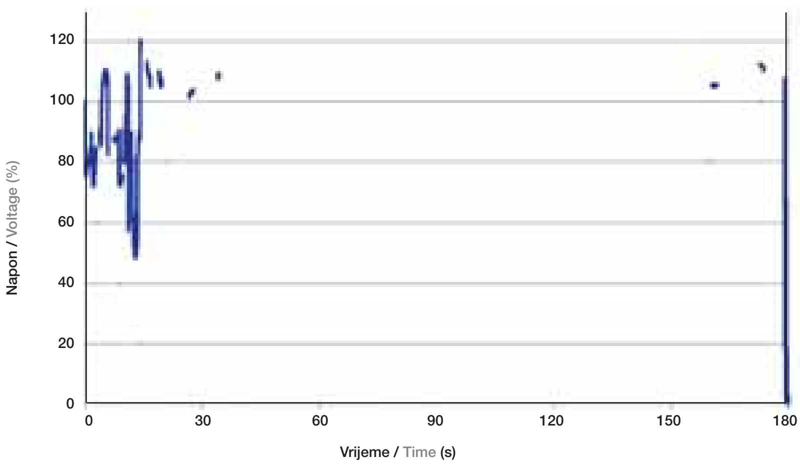



**Slika 6**
Oscilogram 4 – Naponi na sabirnici 66 kV na trafostanici Rhodini
**Figure 6**
Oscillogram 4 – Voltages at 66 kV bus at Rhodini



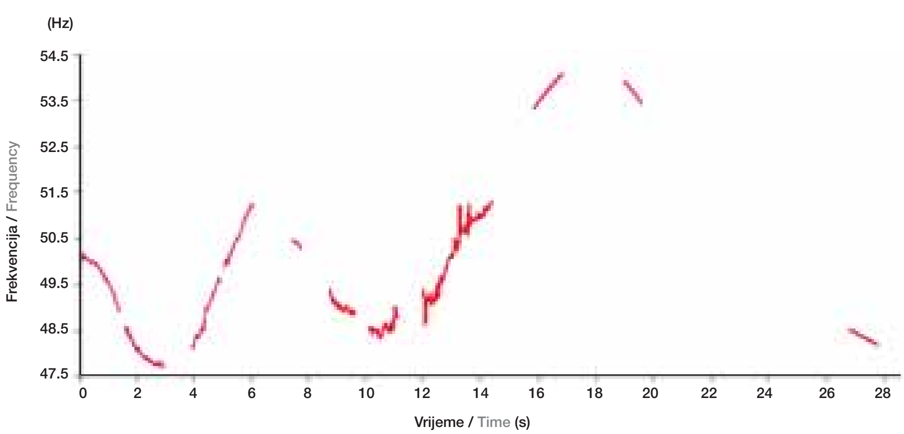


**Slika 7**
Oscilogram 5 – Napon na sabirnici 66 kV na trafostanici Rhodini (nestanak struje vidljiv na kraju)
**Figure 7**
Oscillogram 5 – Voltage at 66 kV bus at Rhodini (blackout seen at the end)





**Slika 8**
Varijacija napona na sabirnici 66 kV (u %) tijekom smetnje
**Figure 8**
66 kV bus voltage variation (in %) during the disturbance





**Slika 9**
Trend varijacije frekvencije zabilježen tijekom smetnje
**Figure 9**
Frequency variation trend registered during the disturbance

# 3 ZAKLJUČCI

Elektroenergetski sustav otoka Rodosa, kao jedan izoliran sustav, osjetljiv je na smetnje. Distribucijski sustav srednjenaponskih nadzemnih vodova u blizini obale također je osjetljiv na učinke morske soli koja negativno utječe na pouzdanost izolacije.

Osjetljivost proizvodnje vjetroelektrana na kolebanja u naponu mreže kao i ukupna zaštita sustava odigrale su ključnu ulogu u razvijanju poremećaja koji je doveo do raspada elektroenergetskog sustava.

Trenutačno se razmatra nadogradnja prijenosnog sustava na otoku Rodosu sa sadašnjih 66 kV na 150 kV što bi se trebalo realizirati u naredne dvije do tri godine. Osim izgradnje prijenosne mreže, potrebno je nadograditi i sustav SCADA te sustave zaštite.

# 3 CONCLUSIONS

As an isolated system, the Rhodes Island system is vulnerable to disturbances. The MV overhead line distribution system in the vicinity of the coast is also vulnerable to the effects of sea salts that adversely affect the reliability of insulation.

The sensitivity of wind generation to voltage swings as well as the overall system protection played a critical role in the development of the perturbation which led to the blackout.

In view of the fact that the transmission system on Rhodes Island is currently being considered for an upgrade from the present 66 kV to 150 kV, scheduled for the next two-to-three years, it is important that the SCADA system is upgraded as well. The protection scheme should also be upgraded.

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Uredništvo primilo rukopis:
2007-07-25

Prihvaćeno:
2007-09-27

Manuscript received on:
2007-07-25

Accepted on:
2007-09-27

# BAZA PODATAKA RELEJNE ZAŠTITE

# RELAY PROTECTION DATABASE

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U radu je prikazan razvoj baze podataka relejne zaštite kroz niz faza. U fazi planiranja baze sagledani su problemi u tipičnom odjelu relejne zaštite i utvrđeno je zašto razvijati bazu podataka. Potom je u fazi analize i specifikacije zahtjeva definirano za što će se baza koristiti. U fazi oblikovanja i izrade baze podataka definiran je njen logički, a potom i fizički model na računalu korištenjem sustava za upravljanje bazom podataka Microsoft Access koji je precizirao kako će baza podataka raditi. Na kraju je baza podataka uvedena u rad provjerom na stvarnim podacima te izobrazbom budućih korisnika. Prikazana baza podataka omogućava sistematizaciju, čuvanje i korištenje velikog broja podataka uz minimalnu redundanciju. Pored toga pruža podršku pri redovnom održavanju uređaja relejne zaštite, izdavanju radnih naloga, periodičkom izvještavanju itd. Bazi podataka relejne zaštite može pristupiti nekoliko korisnika s različitim ovlastima nad pojedinim objektima baze. Pravo pristupa određeno je korisničkim identitetom. Također je kreirana i posebna aplikacija za lakši pregled, ažuriranje i ispis podataka koji omogućava prikaz niza ranije pripremljenih komponenti baze podataka relejne zaštite. Osnovna namjena aplikacije je omogućiti korisniku korištenje pune snage Microsoft Access uz najmanje truda i minimum potrebnog znanja o tehnici baza podataka i sustavu za upravljanje bazom podataka.

The article presents the development of a relay protection database through a series of phases. In the planning phase of the database, problems in a typical relay protection department are examined and the reasons why a database should be developed are determined. Subsequently, during the phase of analysis and the specification of requirements, what the database will be used for is defined. In the phase of the formation and construction of the database, its logic is defined and then a physical model is prepared on a computer using the Microsoft Access database management system, which stipulates how the database will operate. The database is placed into operation and verified using actual data. Training is then provided for the future users. The database presented facilitates the systematization, storage and use of a large quantity of data with minimum redundancy. In addition, it provides support during the regular maintenance of relay protection equipment, the issuing of work orders, periodic reporting etc. The relay protection database can be accessed by several users with differing permissions for individual objects of the database. The right to access is defined by the user identity. Furthermore, a special application has been created to simplify searching updating and printing-out of data, which facilitates the display of a series of previously prepared components of the relay protection database. The basic purpose of the application is to allow the user to utilize the full power of Microsoft Access with a minimum of effort and a minimum of required knowledge about database technique and the system for database management.

Ključne riječi: baza podataka, elektroenergetski sustav, relacijski model podataka, relejna zaštita
Key words: database, electric power system, relational data model, relay protection

# 1 UVOD

Sustavi relejne zaštite u elektroenergetskom sustavu su iznimno važni i istodobno prilično kompleksni. U praksi se koristi puno elemenata različitih proizvođača, uređaji različite tehnološke generacije. Tipični odjeli relejne zaštite (npr. Odjel za zaštitu i mjerenja u HEP Operator distribucijskog sustava d.o.o.) koriste veliku količinu podataka iz različitih izvora čiji se broj neprestano povećava. Radi toga raste potreba za racionalnom i sigurnom pohranom niza podataka te njihovim svrsishodnim korištenjem od strane više korisnika. Primjena modernih informacijskih tehnologija u odjelima relejne zaštite, naročito znanja i tehnika baza podataka, ne samo da pruža veliku pomoć korisnicima, već sve više postaje nužnost.

Baze podataka do danas su najkompleksniji način organiziranja i korištenja pohranjenih podataka. Napredni sustavi za upravljanje bazom podataka kontroliraju složene strukture podataka i integriraju ih u jedinstveni sustav. Svrha sustava baze podataka jest pretvaranje niza podataka u korisne informacije prikazane u obliku pogodnom za korisnika.

Namjera ovoga rada je ukazati na mogućnosti primjene tehnike baze podataka u odjelima relejne zaštite, odnosno odgovoriti na pitanja zašto stvarati bazu podataka, zatim za što će se baza koristiti i na kraju prikazati kako organizirati bazu podataka radi zadovoljenja postavljenih zahtjeva.

# 2 NAMJENA BAZA PODATAKA RELEJNE ZAŠTITE

U odjelu relejne zaštite vrše se poslovi izbora vrste i mjesta ugradnje elemenata relejne zaštite, projektiranje, konfiguriranje i parametriranje releja (podešavanje releja), puštanje uređaja u pogon, zatim redovni i interventni pregledi uređaja u sustavu zaštite, održavanje uređaja itd. Za svaki relej i svaku njegovu funkciju potrebno je imati službenu dokumentaciju odnosno ispitne protokole s tehničkim podacima o releju, ali i vlastite podatke o mjestu ugradnje pojedinog releja i trenutačno postavljenim parametrima. Redovno i povremeno održavanje, ispitivanje i udešenje releja također zahtijeva popratnu dokumentaciju. Posao, tijekom niza godina, obično obavlja više ljudi s različitim pristupom pri formiranju potrebne tehničke dokumentacije, pisanju izvješća itd. Najčešće postoje formulari za upis podataka o nekom zaštitnom releju, no i formulari se povremeno mijenjaju i usklađuju. Također se elementi sustava

# 1 INTRODUCTION

Relay protection systems in an electric power system are exceptionally important and at the same time fairly complex. In practice, many elements from various manufacturers are used as well as equipment from several technological generations. A typical relay protection department (e.g. the Department for Protection and Measurement at the HEP Distribution System Operator (HEP ODS d.o.o.) uses a large amount of data from various sources, which are constantly increasing. Therefore, there is a growing need for the rational and secure storage of data series and their appropriate use by a number of users. The application of modern information technologies in relay protection departments, particularly database knowledge and techniques, not only provides great assistance to users but is increasingly becoming a necessity.

Databases are still the most complex manner of organizing and using stored data. Advanced systems for database management control complex data structures and integrate them into a single system. The purpose of a database system is to transform a series of data into useful information, presented in a form that is suitable for the user.

The purpose of this article is to present possibilities for the application of database technique in relay protection departments, i.e. to answer the questions why a database should be created, what it will be used for and how to organize a database in order to meet the determined requirements.

# 2 THE PURPOSE OF RELAY PROTECTION DATABASES

In a relay protection department, tasks are performed such as the selection of the types and sites for installing relay protection elements, designing, configuring and parametrizing relays, placing equipment into operation, regular and interventional inspections of equipment within the protection system, equipment maintenance etc. For every relay and each of its functions, it is necessary to have official documentation, i.e. testing protocols with technical data on the relay but also particular data on the installation site of an individual relay and the currently set parameters. Regular and periodic maintenance, testing and adjustment of the relay also require accompanying documentation. Over the years, this task is generally performed by several people with differing approaches to the formation of the necessary technical documentation, the writing of reports etc. Most commonly there are forms for data entry on a protective relay but the forms also change occasionally and are zaštite povremeno mijenjaju novijim uređajima, ponekad elementi sustava zaštite mijenjaju mjesto ugradnje ili im se udešene vrijednosti postavljaju na nove iznose. Sve skupa nerijetko rezultira vrlo šarolikom i nesređenom dokumentacijom. Za određeno izvješće često se postavlja pitanje da li je to izvješće posljednje ili postoji neko novije. Odjeli relejne zaštite, očito je, barataju s velikim brojem različitih podataka. Opseg tih podataka se neprestano povećava.

Temeljni cilj pri planiranju baze podataka relejne zaštite bio je stvoriti bazu podataka koja će pomoći korisniku u rješavanju navedenih problema. Veliki broj podataka koji će se čuvati u toj bazi već sada postoje na papiru u raznim formama. Uz to što ih treba sistematizirati i pravilno skladištiti, korisniku treba omogućiti dobivanje izvješća jednaka onima na kakve su već navikli u dosadašnjem radu. Analizom poslovnih procesa u odjelu zaštite došlo se do osnovnih informacijskih zahtjeva na bazu podataka:

– sistematizacija podataka zaštitnih uređaja, s obzirom da se koriste zaštitni uređaji različitih tehnoloških generacija i različitih proizvođača. Uređaji novije generacije obično imaju mnogo veće mogućnosti i mnogo veći skup podataka kojim su definirani od uređaja starije generacije,
– čuvanje niza podataka o zaštitnim uređajima na jednom mjestu u računalu. U bazu podataka treba pohraniti i statičke podatke o elementima zaštite kao tehničke podatke pojedinih uređaja, mjesto ugradnje pojedinih uređaja i sl. te dinamičke podatke o trenutačnom udešenju zaštite, izvršenom ispitivanju,
– evidencija dostupnih podataka i onih zaštitnih uređaja koji trenutačno nisu u pogonu, već su u remontu ili na skladištu,
– posjetnik i podrška pri redovnom održavanju i izdavanju radnih naloga,
– mogućnost uvida u različite skupine podataka i mogućnost ispisa različitih unificiranih izvješća od strane više korisnika različitog profila u odjelu relejne zaštite,
– mogućnost unosa, brisanja i izmjene podataka od strane jednog ovlaštenog korisnika.

Prilikom kreiranja baze podataka nametnuli su se i dodatni zahtjevi i ograničenja:

– baza podataka relejne zaštite mora biti jednostavna za korištenje odnosno potrebni razina znanja korisnika o tehnikama baza podataka te načinu pretraživanja i čuvanja podataka mora biti što niži. Zbog toga, a i zbog važnosti pohranjenih podataka, struktura i integritet podataka moraju biti na visokoj razini,

coordinated. Furthermore, elements of the protection system are periodically replaced by new equipment. Sometimes elements of the protection system are installed in different sites or their values are set to new levels. All of this not infrequently results in a lack of uniformity and highly disorganized documentation. For a specific report, the question is frequently asked whether the report is the most recent or if a newer one exists. Relay protection departments obviously deal with a large quantity of varied data. The range of these data is constantly increasing.

The fundamental goal in the planning of a relay protection database was to create a database that would help the user solve these problems. The great quantity of data that will be stored in the database already exists on paper in various forms. In addition, they must be systematized and stored in an orderly manner. The users must be able to obtain reports identical to those to which they have become accustomed in their work thus far. Analysis of the operational processes in the protection department resulted in the basic information requirements for the database:

– systematization of the data of the protection equipment, since protection equipment of various technological generations and various producers is used. Equipment from more recent generations generally has much greater possibilities and a much larger group of data, in contrast to the equipment of older generations,
– storage of a large amount of data on protection equipment in one place in the computer. In the database, it is also necessary to store static data on the elements of protection such as technical data on individual devices, the installation site of individual devices etc., and dynamic data on real-time protection settings and testing performed,
– records of available data on protective devices that are currently not in operation but are being repaired or stored in a warehouse,
– reminder and support for regular maintenance and the issue of work orders,
– the possibility of inspecting various groups of data and the possibility of printing out various uniform reports by several users of differing profiles in the relay protection department,
– the possibility of entering, deleting and changing data by an authorized user.

When creating the database, additional requirements and limitations have been imposed:

– the relay protection database must be simple to use, i.e. the required level of user knowledge regarding database techniques, searches and data storage must be kept to a minimum. Therefore and due to the importance of the stored data, the data structure and integrity must be at a high level,

- česti problem sličnih baza podataka relejne zaštite je redovno održavanje zbog velikog broja različitih komponenti baze (tablica, upita, izvješća) prilagođenih raznim vrstama i generacijama releja [1]. O ovom problemu također treba voditi računa prilikom dizajniranja baze,
- podaci pohranjeni u bazi također mogu služiti nizu aplikacijskih programa koji se koriste u odjelima zaštite pri proračunu raznih parametara elemenata sustava relejne zaštite (npr. proračunu kratkog spoja u elektroenergetskoj mreži) i sl. Pripremu podataka za aplikacijske proračune moguće je automatizirati koristeći dodatne programske rutine za povezivanje i prilagođene podataka iz baze i aplikacijskih programa [2]. Također je moguće oko baze podataka izgraditi cijeli sustav za rukovanje podacima zaštitnih uređaja, proračunavanje i analizu kvarova, postavljanje parametara releja, provjeravanje, simulaciju itd. [3], [4] i [5]. U ovoj fazi razvoja prikazane baze podataka nije predviđeno automatsko povezivanje aplikacijskih proračuna s podacima u bazi što značajno smanjuje informacijske zahtjeve te količinu potrebnih podataka,
- opseg podataka koje će baza obuhvatiti i prava pristupa određenim skupinama podataka treba prilagoditi postojećoj organizacijskoj strukturi odjela relejne zaštite, a također mjestu odjela relejne zaštite u organizacijskoj shemi cjelokupnog poduzeća. Informacijski zahtjevi koji su postavljeni na bazu podataka relejne zaštite u jednom tipičnom odjelu relejne zaštite, bar u ovom trenutku, nisu obuhvatili i nekakve pomoćne procese kao vođenje knjigovodstva i izdavanje knjigovodstvenih izvješća, proračun amortizacije pojedine opreme, obavljanje financijskih transakcija i slično.

## 3 MODELIRANJE PODATAKA

Modeliranje podataka je proces koji počinje analiziranjem informacijskih zahtjeva, a završava izgradnjom baze podataka [6] i [7]. Postupnim razvojem i transformacijom modela podataka kroz tri razine, što je uobičajeni postupak pri modeliranju podataka, došlo se do realizacije konačnog implementacijskog modela na računalu i stvaranja baze podataka relejne zaštite.

### 3.1 Konceptualni model podataka

Sukladno zahtjevima koji su postavljeni na bazu podataka u prvom koraku, razvijen je konceptualni model tipa entiteti-veze. Model tipa entiteti-veze jedan je od najčešće korištenih modela podataka treće generacije zato što raspolaže sa semantički

- a frequent problem with similar relay protection databases is regular maintenance due to the large number of various base components (tables, queries and reports) adapted to various types and generations of relays [1]. This problem must also be taken into account when designing the database,
- data stored in the base can also be used in a series of application programs employed by protection departments for the computation of various parameters of the relay protection system elements (e.g., calculation of a short circuit in the electric power network). Preparation of data for calculation applications can be automated by using additional program routines for linking and adapting data from the base and – application programs [2]. Furthermore, it is possible to construct an entire system around the database for the data management of protective equipment, calculation and analysis of faults, establishment of relay parameters, verification, simulation etc. [3], [4] and [5]. In this phase of the development of the database presented, automatic linking of the application software with data in the base has not been anticipated, thereby significantly reducing the information requirements and the quantity of data needed,
- the range of data that the base will cover and the right to access certain groups of data should be adjusted to the existing organizational structure of the relay protection department and the position of the relay protection department within the organizational schema of the entire enterprise. Information requirements placed upon the relay protection database in a typical relay protection department, at least at the moment, do not cover any auxiliary processes such as bookkeeping and issuing bookkeeping reports, calculation of the depreciation of individual equipment items, performance of financial transactions etc.

## 3 DATA MODELING

Data modeling is a process that begins with the analysis of information requirements and ends with the construction of a database [6] and [7]. The progressive development and transformation of a data model through three levels, which is the customary approach in data modeling, resulted in the implementation of the model on the computer and the creation of the relay protection database.

### 3.1 Conceptual data model

Based upon the requirements established for the database in the first step, a conceptual model of the entity-relationship type was developed. A model bogatim, prirodnim i korisniku bliskim konceptima, lako se transformira u klasične komercijalne modele, a prikladan je i za daljnje projektiranje baze podataka. Pri izradi modela podataka entiteti-veze vodilo se računa da podaci budu međusobno neovisni te da se jedan podatak nalazi samo na jednom mjestu. Na ovaj način model podataka može se graditi modularno, a iz modela podatka mogu se izlučivati podmodeli.

Tijekom modeliranja podataka također se vodilo računa o tome da je ovo samo jedan projekt, odnosno jedan podsustav unutar većeg globalnog modela podataka. Stoga se težilo strogom poštivanju pravila pri oblikovanju podataka kako bi se kasnije omogućila razmjena podataka drugim aplikacijama [8] i [9]. Cilj strateškog planiranja velikih informacijskih sustava i jest podjela sustava na dijelove koji se mogu realizirati malim projektima autonomno te relativno stabilna infrastruktura, u kojoj se manji, modularno projektirani podsustavi lako mogu povezati.

Tijekom izrada modela entiteti-veze najprije su definirani tipovi entiteta (energetski objekt, postrojenje, polje, strujni transformator, jezgra strujnog transformatora itd.) i njihovi tipovi atributa (funkcija polja, proizvođač strujnog transformatora, nazivna struja jezgre strujnog transformatora itd.) odnosno uočeni su i razlučeni entiteti i atributi. S obzirom da su neki entiteti grupirani (klasificirani) prema zajedničkim svojstvima izvršena je preraspodjela entiteta prema klasifikacijskim strukturama. Potom su definirane veze među entitetima i njihove karakteristike. Na kraju je nekoliko podmodela (podmodel energetskog transformatora, podmodel mjernih transformatora itd.) objedinjeno u zajednički model podataka tipa entiteti-veze.

### 3.2 Logički model podataka

Kada je konceptualni model zadovoljio postavljene zahtjeve, postupkom logičkog modeliranja pretvoren je u relacijski model podataka. Relacijski model podataka je izabran za logički model s obzirom da je to najpopularniji model komercijalnih sustava za upravljanje bazom podataka, a struktura modela je jednostavna. Dobivena logička shema baze podataka je provjerena prema zahtjevima korisnika.

Dio sheme relacijske baze podataka prikazan je na slici 1. U relacijama prikazanim na slici vidi se samo dio atributa kako slika ne bi bila prevelika. Model podataka je prilično složen s obzirom da se u praksi koristi niz različitih vrsta zaštita, a svaka opet više različitih tipova uređaja i različitih generacija izvedbe. Uz identifikacijske i opisne podatke, u model podataka integrirane su razne

of the entity-relationship type is one of the most frequently used third-generation data models because it employs semantically rich, natural and user-friendly concepts; can easily be transformed into classical commercial models and is suitable for the further design of a database. In developing the entity-relationship data model, it was stipulated that the data would be mutually independent and each data entry would be located in only one place. In this manner, the data model could be built modularly and submodels could be extracted.

During data modeling, it was taken into account that this is only one project, i.e. one subsystem within a larger global data model. Therefore, there is a tendency to respect rules more strictly when forming data to facilitate data exchange with other applications in the future [8] and [9]. The goal of the strategic planning of a large information system is the division of the system into parts, which can be achieved autonomously with small projects and a relatively stable infrastructure, within which smaller, modularly designed subsystems can be easily linked.

During the preparation of an entity-relationship model, first of all the types of entities (power system facilities, bays, current transformer, current transformer core etc.) are defined and their attributes (bay function, current transformer manufacturer, rated current of the current transformer core etc.), i.e. entities and attributes are noted and differentiated. Since some entities are grouped (classified) according to common properties, the entities were reconfigured according to the classification structures. Then the relationships among the entities and their characteristics were defined. Finally, several submodels (a submodel of a power transformer, a submodel of the measurement transformers etc.) were combined into a common data model of the entity-relationship type.

### 3.2 Logic Data Model

When a conceptual model has met the established requirements, it is transformed into a relational data model through the procedure of logical modeling. A relational data model has been chosen for the logic model because it is the most popular model used in commercial systems for database management, and the model structure is simple. The logic schema obtained of the database is verified according to user requirements.

Part of the schema of the relational database is presented in Figure 1. In the relationships shown in the figure, only a part of the attributes are seen so that the figure is not too large. The data model is fairly complex because a series of various types of slike (npr. jednopolne sheme), dijagrami i sl. Prikazani logički model podataka je još uvijek neovisan od konkretnog sustava za upravljanje bazom podataka.

### 3.3 Fizički model podataka

U posljednjoj fazi modeliranja podataka logički model podataka postupkom fizičkog modeliranja pretvoren je u fizički model i realiziran na računalu pomoću sustava za upravljanje bazom podataka Microsoft Access 2000. Prilikom izrade fizičkog modela velika pažnja je posvećena osiguranju integriteta podataka, a time stabilnosti i pouzdanosti buduće baze podataka u radu. Fizičko modeliranje je, uz određivanje formata fizičkog zapisa svih atributa definiranih u prethodnoj fazi (izbor vrste podataka i alokacija prostora), obuhvatilo definiranje niza kontrola koje pridonose minimalizaciji pogrješaka kod unosa podataka, indeksiranje pojedinih atributa radi kasnijeg bržeg i sigurnijeg pretraživanja. Procedure za kontroliranje ispravnost unesenih podataka provjeravaju da li su podaci unutar određenih graničnih vrijednosti kod podataka gdje je ta ograničenja moguće definirati, za neke podatke pružaju korisniku listu mogućih vrijednosti s tim da mu nekad dozvoljavaju i drugi izbor, a nekad ne. Za podatke, gdje je to bilo potrebno, definirane su maske za unos, nekim podacima su odmah upisane pretpostavljene vrijednosti koje se kasnije mogu promijeniti itd. Realizacijom fizičkog modela na računalu nastala je baza podataka relejne zaštite.

Microsoftov sustav za upravljanje bazom podataka odabran je iz dva razloga:

– Access 2000 (i novije verzije) prema svojim mogućnostima i popularnosti danas spada među vodeće programe za baze podataka na PC platformama,
– ako podaci nadrastu mogućnosti Accessa 2000 posebnom procedurom ugrađenom u Accessu 2000 lako ih je premjestiti na Microsoft SQL Server koji je dovoljno snažan za gotovo sve zahtjeve.

Performanse koje pruža Access 2000 sasvim su dostatne da zadovolje zahtjeve koji su u početku postavljeni na ovu bazu podataka [10] i [11]. Ukoliko se u budućnosti postave stroži zahtjevi na sustav za upravljanje bazom podataka kao veći opseg podataka, više korisnika, više istodobnih transakcija, poboljšana sigurnost itd., baza se može proširiti na SQL Server. Također, ako se ukaže potreba za integriranjem ove baze podataka s drugim bazama, mogućnost prelaska na Microsoft SQL Server verziju može biti od velike koristi.

protection are used in practice, and for each there are several different types of equipment of different generations. In addition to the identification and descriptive data, various figures are integrated into the data model (e.g. single-pole schemata), diagrams etc. The logic data model shown is still independent from the concrete database management system.

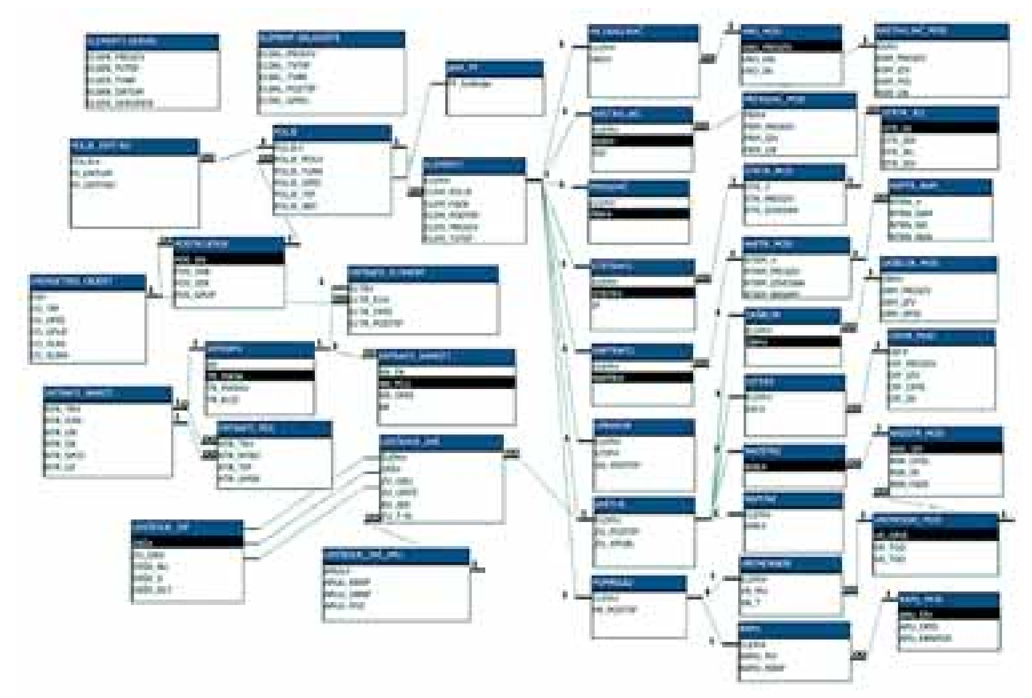
### 3.3 Physical Data Model

In the final phase of data modeling, the logic data model is transformed into a physical model through the procedure of physical modeling and realized on a computer using the Microsoft Access 2000 database management system. During the development of the physical model, great attention has been devoted to assuring the integrity of the data and, thereby, the stability and reliability of the future database in operation. Physical modeling, in addition to the determination of the format for the physical record of all the attributes defined in the previous phase (the selection of the types of data and the allocation of space), is the definition of a series of controls that contribute to minimizing errors in data entry and the indexing of individual attributes to facilitate more rapid and dependable searches later. The procedures for controlling the accuracy of the data entered verify whether the data are within the specified limit values for data where this limit can be defined. For some data, the user is offered a list of possible values. Sometimes another choice is permitted and sometimes not. Where necessary, data entry forms are defined and the assumed values for some data are entered immediately, which can be changed later etc. With the implementation of the physical model on the computer, a relay protection data base was created.

The Microsoft database management system was chosen for two reasons:

– Access 2000 and newer versions are among the leading database programs on PC platforms today, in terms of their possibilities and popularity.
– if the data outgrow the capabilities of Access 2000, a special procedure installed in Access 2000 makes it is easy to transfer them to a Microsoft SQL Server that is sufficiently powerful for nearly all requirements.

The performance provided by Access 2000 is fully sufficient to meet the requirements established at the beginning for this database [10] and [11]. If stricter requirements are set in the future on the system for database management such as a larger range of data, more users, more simultaneous transactions, improved security etc., the base can be extended to the SQL Server. Furthermore, if the need is demonstrated for the integration of this database with other bases, the possibility for transfer to the Microsoft SQL Server version could be very useful.



**Slika 1**
Dio relacijske sheme baze podataka
**Figure 1**
Part of the relationship schema of the database

## 4 SIGURNOST BAZE PODATAKA RELEJNE ZAŠTITE

Sustav za upravljanje bazom podataka MS Access 2000 nudi nekoliko sigurnosnih opcija za očuvanje integriteta i tajnosti podataka koje su iskorištene pri kreiranju baze podataka relejne zaštite. Sigurnost na razini korisnika kombinira korisnike, radne grupe i dozvole na razini objekta za potporu ograničenom pristupu različitim dijelovima baze podataka. Kod pokretanja programa MS Access 2000 potrebno je unijeti korisničko ime i lozinku za definiranje korisničkog identiteta. Korisničko ime je povezano sa skupom dozvola koje određuje što korisnik može raditi nad pojedinim objektima baze kad se baza podataka otvori. U bazi podataka relejne zaštite definirane su tri grupe korisnika s različitim pravima:

- administrator baze - ima mogućnost izmjene dizajna i strukture baze te pregled i ažuriranje podataka u bazi,
- ovlašteni korisnik - ima mogućnost pregleda i izmjene podataka u bazi, ali nema mogućnost izmjene dizajna i strukture baze,
- obični korisnici - imaju samo mogućnost pregleda podataka.

Grupne ovlasti administratora baze i grupne ovlasti ovlaštenog korisnika ima po jedan korisnik dok ovlasti grupe obični korisnici ima više korisnika.

## 4 SECURITY OF THE RELAY PROTECTION DATABASE

The MS Access 2000 database management system offers several security options for safeguarding the integrity and secrecy of the data that are used in creating a relay protection database. Security at the user level encompasses users, work groups and permission at the level of the object to support limited access to various parts of the database. When starting the MS Access 2000 program, it is necessary to enter the user name and password for the definition of the user's identity. The user's name is linked with a set of permissions that determine what a user can do regarding individual objects of the base when the database opens. In the relay protection database, three groups of users with different rights are defined:

- the base administrator can change the design and structure of the base as well as view and update the data in the base,
- the authorized user can view and change data in the base but cannot change the design and structure of the base,
- the ordinary users can only view data.

The administrator group permissions and the user group permissions have one user each while permissions for the group of ordinary users are held by several users. Individual users in this group can be

Pojedinim korisnicima u ovoj grupi mogu se dati dodatne ovlasti nad nekim objektima baze kao na primjer mogućnost dodavanja podataka u neke tablice, ali bez mogućnosti brisanja ili izmjene postojećih podataka. Ovlasti grupa i korisnika nisu trajno definirane jer administrator baze podataka u svakom trenutku može ovlasti promijeniti ili dodati novog korisnika. Prirodno je da ovlasti ovlaštenog korisnika dobije osoba u odjelu zaštite zadužena za ispravnost unesenih podataka.

Baza podataka relejne zaštite je, za sada, zamišljena i prilagođena čuvanju i održavanju na jednom PC računalu (najvjerojatnije računalu ovlaštenog korisnika) uz mogućnost korištenja kopija za pregled na drugim računalima. Također je moguće dozvoliti rad nad bazom podataka s drugih računala u lokalnoj mreži. Tada se postavkom lokalne mreže definiraju računala s kojih se može pristupiti i s kakvim ovlastima (samo čitanje ili čitanje uz mogućnost ažuriranja i sl.).

Uz sigurnost na razini korisnika uvedena je i dodatna zaštitna mjera u obliku lozinke na bazu podataka. Ovu lozinku se ne smije brkati s korisničkom lozinkom pri pokretanju MS Accessa 2000. Dakle za rad s bazom podataka relejne zaštite nakon prijavljivanja korisnika (upis korisničkog ime i lozinke) još je potrebno unijeti i lozinku baze podataka relejne zaštitite kao drugu razinu sigurnosti.

## 5 APLIKACIJA ZA PREGLED, AŽURIRANJE I ISPIS PODATAKA

Sustav za upravljanje bazom podataka MS Access 2000 uz razne mogućnosti pri konstrukciji tablica i upisu podataka nudi niz vrlo moćnih alata za pregledavanje baze podataka, postavljanje različitih upita, kreiranju izvješća i njihovo prilagođavanje ispisu na papir. Za uspješno korištenje baze podataka i svih prednosti koja ona pruža nužno je određeno znanje iz tehnike baze podataka te poznavanje rada s programom MS Access. Program MS Access također nudi niz alata za automatizaciju rada i brz pristup često korištenim dijelovima baze bez poznavanja pojedinih komponenti i njihovih međusobnih odnosa. Koristeći te alate kreirana je posebna aplikacija za lakši pregled, ažuriranje i ispis podataka iz baze relejne zaštite s mogućnošću aktiviranja niza pripremljenih upita, ekranskih obrazaca i izvješća. Aplikacija u svom radu koristi i ostale komponente baze podataka kao makronaredbe i programske rutine napisane u programskom jeziku Microsoft VBA (Visual Basic for Applications) kako bi se u potpunosti iskoristila snaga Accessa. Osnovna namjena aplikacije

given additional permissions for some of the database such as, for example, the option of adding data to some tables, but without the option of deleting or changing existing data. Group and user permissions are not permanently defined because the administrator of the database can change permissions at any moment or add new users. It is natural for the permission of an authorized user to be obtained by a person in the security department in charge of the accuracy of the data entered.

The relay protection database is, for now, conceived and adapted for storage and maintenance on one PC (most likely the computer of the authorized user), with the possibility of using copies for searching on other computers. Furthermore, it is possible to permit work on the database from other computers in the local network. In this case, the settings of the local network define the computers from which the database can be accessed and the types of permissions (read only or read with the option of updating etc.).

In addition to security at the user level, an additional security measure has been introduced in the form of a password for the database. This password must not be confused with the user password for starting MS Access 2000. Thus, in order to work with the relay protection database, after entering the user's name and password it is also necessary to enter the password of the relay protection database as a second level of security.

## 5 APPLICATION FOR INSPECTING, UPDATING AND PRINTING-OUT DATA

The MS Access 2000 database management system, in addition to various options in the construction of tables and data entry, also offers a series of very powerful tools for searching the database, posing various queries, creating reports and adapting them for hard copies. For the successful use of the database and all the advantages that it offers, a certain amount of knowledge of database technique and the use of the MS Access program is necessary. The MS Access program also offers a series of tools for automating work and rapidly accessing frequently used parts of the base, which due not require familiarity with the individual components and their mutual relationships. Using these tools, a special application has been created to facilitate the searching, updating and printing-out of data from the relay protection database, with the option of activating a series of prepared queries, screen forms and reports. The application also uses other components from the database such as macro instructions and program routines written in the proje omogućiti korisniku što lakše korištenje svih pripremljenih komponenti konkretne baze podataka relejne zaštite uz najmanje truda korisnika i minimum potrebnog znanja o tehnici baza podataka i samom MS Accessu. Korištenjem aplikacije, korisnik ne treba znati puno niti o samom modelu podataka relejne zaštite. Aplikacija je slagana tako da u radu nastoji ponuditi korisniku baš ono što mu određenom trenu može zatrebati. Općenito aplikacija omogućava:

– vođenje korisnika kroz različite opcije, aktiviranje pojedinih komponenti baze i logično kretanje kroz upisane podatke (vertikalno i horizontalno) koristeći niz izbornika,
– korištenje niza ekranskih formi (obrazaca) za lakši pregled, upis i ažuriranje podataka u tablicama s više ugrađenih filtara za pregled i razvrstavanje podataka. Unos podataka putem obrazaca je daleko intuitivniji od direktnog unosa u tablice uz bolji estetski dojam što rad čini ugodnijim i manje zamornim. Uporabom posebno kreiranih dodatnih komandnih tipki u obrascu za npr. trenutačni pregled neke druge tablice, prijelaz na drugi obrazac, pregled različitih uputa za unos itd., rad postaje sigurniji i mnogo brži. Korištenjem složenih obrazaca omogućen je istodobni rad nad više relacijski povezanih tablica (slika 2),
– korištenje pripremljenih parametarskih upita i složenih upita npr. sumarni pregled udešenja zaštite u željenom objektu. Parametarski upiti služe za lociranje specifičnih slogova već kod poziva upita. Složeni višetablični upiti s nizom kriterija uz uporabu matematičkih i logičkih operatora su također vrlo efikasan način pretraživanja baze,
– poziv različitih unificiranih obrazaca za ispis podataka iz baze, npr. izvješće o udešenju zaštite u vodnim poljima nekog objekta, izvješće o udešenju zaštite u nekom polju, sumarno izvješće o udešenju zaštite u odabranom elektroenergetskom objektu (slika 3) itd. Informacije u izvješćima su grupirane na način prikladan za tiskanje na više stranica. Oblik izvješća kreiran je tako da izvješće iz baze izgleda jednako kao dokumentacija koja se do sada koristila za prikaz podataka ugrađenih uređaja relejne zaštite u postrojenjima (slika 4),
– pregled popratne dokumentacije, npr. način označavanja (šifriranja) elemenata nekog polja, opis svake tablice itd. Uz ugrađeni sustav pomoći koji pruža sam program MS Access, npr. ispis opisa svakog polja u dnu monitora pri kretanju kroz tablicu i sl., unutar aplikacije na više mjesta mogu se pozvati posebno kreirani dokumenti s popratnim objašnjenjima. Postoje sljedeći takvi dokumenti:

gramming language Microsoft VBA (Visual Basic for Applications) in order to utilize the power of Access fully. The basic purpose of the application is to enable the user to employ all the prepared components of the actual relay protection database as easily as possible, with the minimum of user effort and the minimum necessary knowledge of database technique and MS Access. When using the application, the user also does not have to know a lot about the relay protection data model. The application is constructed in such a manner that it attempts to offer the user precisely that which he or she would need at a particular moment. Generally, the application makes the following possible:

– guiding the user through various options, activating individual base components and moving logically through the entered data (vertically and horizontally) using a series of menus,
– using a series of screen forms to facilitate the searching, entry and updating of data in the tables with several installed filters for the searching and classification of data. Entry of data via forms is far more intuitive than direct entry into tables and creates a better esthetic impression, so that work becomes more pleasant and less tiring. By using specially created additional command keys in the form for, e.g. the instantaneous view of some other table, switching to another form, reading various instructions, entry etc., operation becomes more secure and much faster. By using complex forms, it is possible to work on several relationally connected tables at the same time (Figure 2),
– using prepared parameter queries and crosstab queries, for example a summary review of the protective settings in a desired object. Parameter queries serve for locating specific records with query calls. Complex multi-relational queries with a series of criteria using mathematical and logical operators are also very effective means for searching the base,
– calling various standardized forms for the printout of data from the base, e.g. reports on protection settings in the transmission line bays of some facility, reports on protection settings in some bay, a summarized report on the protection settings in a selected electrical power facility (Figure 3) etc. Information in the reports is grouped in a manner that is suitable for printing on several pages. The form of the reports is created so that the reports from the database look the same as documents that have been used until now for presenting the data on the installed relay protection equipment in facilities (Figure 4),
– inspection of accompanying documentation, e.g. the manner of coding the elements of a bay, description of each table etc. In addition to the

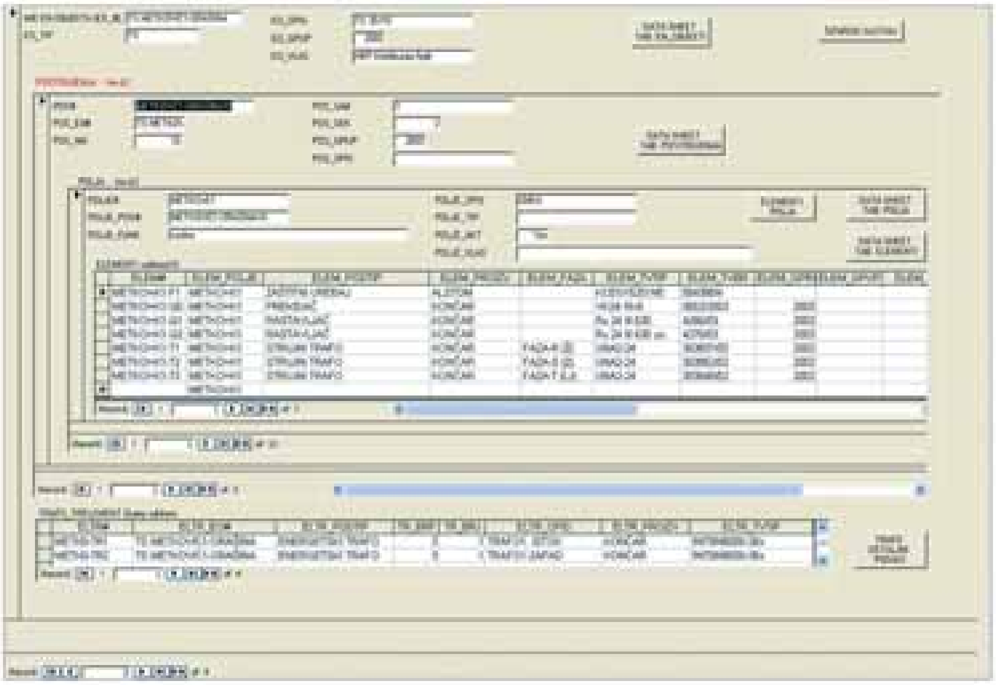
- opis svih relacija u bazi podataka relejne zaštite, s opisom svih atributa iz relacijske sheme te relacijskim vezama među tablicama,
- opis šifarskog sustava koji se koristi pri definiranju i upisu primarnog ključa za svaku relaciju,
- tekstualni opis rada aplikacije za pregled, ažuriranje i ispis podataka s opisom svih izbornika, formi, izvješća itd., odnosno detaljne upute za korištenje ove aplikacije,
- blok dijagram toka aplikacije za pregled, ažuriranje i ispis podataka koji služi za brzo snalaženje unutar hijerarhijske strukture kreiranih izbornika.

Sve opcije koje nudi ova aplikacija mogu se obaviti i bez njenog aktiviranja (ako korisnik ima ovlasti da to obavi), ali tada treba dobro poznavati strukturu podataka i tehnike dizajniranja komponenti baze podataka ili pak nazive ranije kreiranih obrazaca, upita i izvješća koja se pozivaju u aplikaciji. Akcije nad bazom podataka koje nisu predviđene u aplikaciji mogu se obaviti izvan aplikacije. Dizajn aplikacije može mijenjati samo administrator baze dok kreiranje novih izvješća, upita i sl. mogu raditi svi korisnici. Ukoliko se ukaže potreba za novim sadržajima u aplikaciji ili npr. netko od korisnika iz grupe običnih korisnika kreira upit koji se često koristi, administrator baze ga može ukomponirati u aplikaciju.

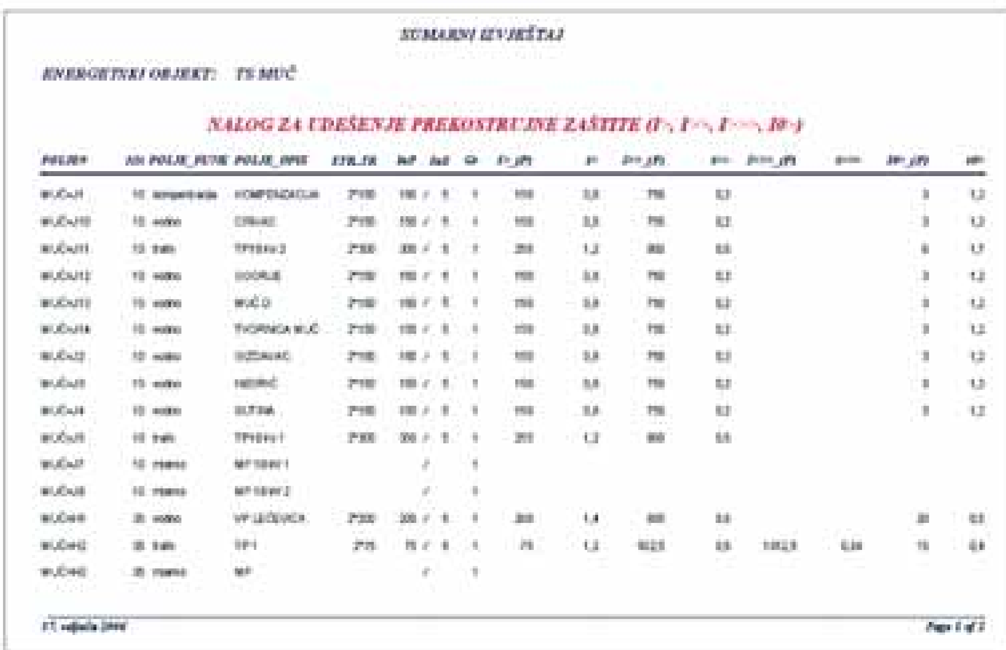
installed help system that the MS Access program provides, e.g. a print-out of a description of each bay on the bottom of the monitor when moving through a table etc., within applications in several places it is possible to call specially created documents with accompanying explanations. There are the following such documents:

- description of all the relationships in the relay protection database, with a description of all the attributes from the relational schema and the relational links among the tables,
- description of the code system that is used in defining and entering the primary key for each table,
- the textual description of the operation of the application for the searching, updating and print-out of data with a description of all the menus, forms, reports etc., i.e. detailed instructions for using these applications,
- a block diagram of the application flow for searching, updating and printing data that provides rapid orientation within the hierarchical structure of the created menus.

All the options offered by this application can also be performed without activating it (if the user has permission to do so), in which case it is necessary to be well acquainted with the structure of the data and the technique of designing database components or the names of previously created forms, queries and reports that are called in the application. Actions on the database that are not anticipated in the application can be performed outside the application. The application design can only be changed by the database administrator although the creation of new reports, queries etc. can be performed by all users. If the need arises for new contents in the application or, for example, one of the users from the group of ordinary users creates a query that is frequently used, the database administrator can incorporate it in the application.



**Slika 2**
Složena ekranska forma
**Figure 2**
Complex screen form




**Slika 3**
Sumarno izvješće o udešenju zaštite u elektroenergetskom objektu TS Muć
**Figure 3**
Summary report on the protection settings in the Muć Substation

**Slika 4**
Izvješće o udešenju zaštite u vodnom polju H1 u transformatorskoj stanici Metković1- Orašina
**Figure 4**
Report on the protection settings at the H1 power line bay in the Metković1- Orašina Substation

| | | | | | |
|---|---|---|---|---|---|
| ENERGETSKI OBJEKT | TS METKOVIĆ1-ORAŠINA | | | OBJEKT OPIS | TS 35/10 |
| POLJE# | METKO=H1 | FUNKCIJA | vodno | POLJE NAZIV | METKOVIĆ2 |

| | | | |
|---|---|---|---|
| PREKIDAČ | KONČAR | | |
| TVORN. TIP | VK38-16-8 | | |
| TVORN. BROJ | 0126/2001 | | |
| IZVEDBA | VAKUUMSKI KOMPAKTNI | | |
| Un (kV) | 38 | | |
| Ip (kA) | 16 | In (A) | 800 |
| MOTORNI POG. | ✔ | U mot | 110 V DC |

| | |
|---|---|
| UPRAVLJAČKI UREĐAJ | |
| TVORN. TIP | |
| TVORN. BRO | |

| | | | | | |
|---|---|---|---|---|---|
| STRUJNI TRANSFORMATOR | KONČAR | | | | |
| TVORN. TIP | INA2-38 | | | | |
| TV.BR. R | 203398/02 | 203397/02 | 203400/02 | | |
| IZVEDBA | INA | Broj jezgri | 2 | | |
| In.PRIMARA | 2*200 | SPOJEN (A) | 400 | | |
| Ith (A) | 2*240 | Idin (A) | 40 | | |
| Unpm Ui/ Uui (kV) | 36 | 70 | 170 | | |
| kl.izol. | B | masa (kg) | 30 | Ext (%) | 120 |

| JEZ | In(A) | Sn(VA) | KL | SV | STEZ1 | STEZ2 |
|---|---|---|---|---|---|---|
| 1 | 5 | 10 | 0.5 | Fs10 | | |
| 2 | 5 | 30 | 10P | 10 | | |
| | | | | | | |

| ZAŠTITNI RELEJI | F1 | F2 | F3 |
|---|---|---|---|
| PROIZVOĐAČ | ALSTOM | ALSTOM | |
| TVORN. TIP | KCEG14201N51EED | KVTL10001L15AEH | |
| TVORN. BROJ | 584379N | 584324N | |

| ZAŠTITA | GR | UDEŠENJE | | T (S) | KUT | BL | MOD | APU(tkop-tbnp-st) | APU - opis | DATUM | ISPITAO |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | |
| I> | 1 | 3,75 | A | 1,6 | 45 | | | | | | |
| I>> | 1 | 18,75 | A | 0,8 | 45 | | | | | | |
| I>>> | 1 | 15 | A | 0,1 | | | | | | | |
| I0> | 1 | 0,25 | A | 1,1 | 0 | | | | | | |
| I0>>> | 1 | 0,375 | A | 0,4 | | | | | | | |
| I> | 2 | 3,75 | A | 1,6 | | | | | | | |
| I>> | 2 | 18,75 | A | 0,8 | | | | | | | |
| I>>> | 2 | | | | | ✔ | | | | | |
| I0> | 2 | 0,375 | A | 1,1 | | | | | | | |
| I0>>> | 2 | | | | | ✔ | | | | | |

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# 6 TESTIRANJE BAZE PODATAKA I OBUKA KORISNIKA

Prije uvođenja baze podataka relejne zaštite u rad izvršena su temeljita testiranja svih njenih dijelova i obuka korisnika.

Prva testiranja i ocjena performansi rađena su u fazi logičkog modeliranja na relacijskom modelu podataka. Dobar relacijski model s minimalnom logičkom redundancijom podataka osnova je svake dobre baze podataka koja će dugo vremena moći udovoljiti postavljenim zahtjevima. Vrednovanje relacijskog modela radilo se tako što su simulirana pretraživanja i grupiranja podataka na način kako će to vjerojatno raditi budući korisnici baze relejne zaštite. Operacijama relacijske algebre (projekcije, restrikcije, prirodno spajanje itd.) nad definiranim relacijama iz relacijskog modela kreirani su različiti pogledi u podatke (izvedene relacije) radi izdvajanja informacija koje će zanimati korisnike. Također je provjereno da su sve relacijske sheme modela podataka bar u 3. normalnoj formi, kako traži teorija relacijskih modela podataka, čime se izbjegavaju određene anomalije u strukturi baze podataka.

Nakon što je relacijski model podataka zadovoljio postavljene uvjete implementiran je na računalo i ponovno testiran sada kao fizički model. Kako bi provjerili cjelokupan model podataka i njegovo ponašanje u realnim uvjetima uneseni su podaci o elementima relejne zaštite jedne kompletne transformatorske stanice (TS 35/10 kV Muć). Provjereni su odnosi atributa u relacijama, veze među relacijama te formati zapisa pojedinih atributa.

Kad su otklonjeni svi uočeni nedostatci na modelu podataka realizirana je aplikacija za unos, pregled i ažuriranje podataka. Rad kompletne aplikacije provjeren je na način da su podaci elemenata relejne zaštite drugog objekta (TS 35/10 Metković1 – Orašina) uneseni korištenjem aplikacije. Također su na podacima ove dvije transformatorske stanice testirane i dorađene ekranske forme za pregled podataka, različiti upiti te tiskana izvješća iz baze.

U zadnjoj fazi pripreme baze za rad, budući korisnici su najprije upoznati sa svim opcijama, a potom su oni vrednovali mogućnosti baze podataka. Iako je cijeli projekt razvijan u bliskoj suradnji s korisnicima i u ovoj fazi uvaženo je više njihovih sugestija i prijedloga. Kraj procesa testiranja je zaključen unosom podataka o elementima relejne zaštite još jedne transformatorske stanice (TS 35/10 kV Trogir) od strane korisnika.

# 6 DATABASE TESTING AND USER TRAINING

Prior to placing the relay protection database into operation, thorough testing of all its parts was performed and the users were trained.

The first testing and performance evaluations were conducted in the logical modeling phase on the relational data model. A good relational model with minimal logical data redundancy is the basis of every good database that will be able to meet the set requirements over a long period of time. Evaluation of the relational model was performed in such a manner that searches and grouping of data were simulated in the manner that future users of the relay protection database will probably employ. Through operations of relational algebra (projections, restrictions, natural join etc.) on defined relationships from the relational model, various views of the data are created (derived) in order to select information that will interest users. It has also been confirmed that all the relational data models are at least in the third normal form, as required by the theory of relational data models, thereby avoiding certain anomalies in the database structure.

After the relational data model satisfied the established prerequisites, it was implemented on the computer and retested as a physical model. In order to verify the entire data model and its behavior under real conditions, data were entered on elements of the relay protection of a complete substation (Muć 35/10 kV Substation). The connections among the attributes in the relations, the relationships among the relations and the formats of the records of individual attributes were evaluated.

When all the noted shortcomings of the data model were eliminated, the application for entering, searching and updating data was implemented. The operation of the complete application was verified in a manner that the data of the elements of relay protection at a second facility (Metković1 – Orašina 35/10 kV Substation) were entered by using the application. Furthermore, the screen forms for searching data, various queries and printed reports from the database were tested and revised using data from these two substations.

In the final phase of preparing the database for operation, future users were acquainted with all the possibilities in advance. They then evaluated the possibilities of the database. Although the entire project was developed in close collaboration with the users, many of their suggestions and proposals were taken into account in this phase as well. The testing process was concluded with the entry of data on the relay protection elements for one more substation (Trogir 35/10 kV Substation) by the users.

## 7 ZAKLJUČAK

Razvoj i održavanje informacijskog sustava u uvjetima intenzivnog tehnološkog napretka je vrlo opsežan i složen posao. Nužno je imati dugoročnu viziju razvoja koja će biti kompatibilna s postojećim te fleksibilna u prihvaćanju novih tehnologija. Izgradnja informacijskog sustava kroz dijelove koji se mogu samostalno realizirati, a potom povezati u cjelinu jer poštuju sva pravila pri kreiranju modela podataka i izgradnje baze podataka je dobar pristup.

U radu je opisana koncepcija baze podataka zaštitnih uređaja za potrebe odjela relejne zaštite. Prikazan je i opisan razvoj modela podataka zaštitnih uređaja koji poštuje uobičajene standarde i principe izgradnje. Nad modelom podataka razvijena je aplikacija za pregledavanje, izvještavanje i ažuriranje podataka u bazi koja je također opisana. Ovakva baza podataka može funkcionirati kao samostalna cjelina, a također se može integrirati u svoju okolinu. Jasno da se ovakva baza podataka može prilagoditi potrebama konkretnih odjela relejne zaštite dodavanjem novih relacija u relacijskom modelu, dodavanjem novih pregleda i preoblikovanjem izvješća.

## 7 CONCLUSION

The development and maintenance of an information system under conditions of intensive technological advancement is a very extensive and complex task. It is necessary to have a long-term vision of development that will be compatible with existing technologies and flexible in the acceptance of new ones. The construction of the information system using parts that can be independently developed and then combined into a whole is a good approach because all the rules are respected in the creation of the data model and the construction of the database.

The article describes the concept of a protective equipment database for the needs of a relay protection department. A description is also presented of the development of the data model for protective equipment that follows the customary standards and principles of construction. Based upon the data model, an application has been developed for the searching, reporting and updating of data in the base, which is also described. Such a database can function as an independent entity and can also be integrated into its environment. Clearly, such a database can be adapted to the needs of actual relay protection departments by adding new relations in the relational model, adding new views and restructuring reports

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Uredništvo primilo rukopis:
2007-09-30

Prihvaćeno:
2007-10-22

Manuscript received on:
2007-09-30

Accepted on:
2007-10-22

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