energija

| ekonomija | ekologija

САВЕЗ ЕНЕРГЕТИЧАРА

1919

2020

ASSOCIATION OF ENERGY SECTOR SPECIALISTS

ENERGETIKA 2020

energija | ekonomija | ekologija

MONOGRAFIJA
XXXV Međunarodnog savetovanja
u organizaciji Saveza energetičara

ENERGETIKA 2020

ZBORNIK RADOVA
CONFERENCE PROCEEDINGS

21-24. jun 2020. godine
Hotel Palisad, Zlatibor

SAVEZ ENERGETIČARA
Prof. dr Nikola Rajaković
Elektrotehnički fakultet Univerziteta u Beogradu
Bulevar kralja Aleksandra 73
11120 Beograd
Srbija
info@savezenergeticara.org

www.savezenergeticara.org

Energija / Ekonomija / Ekologija
Monografija XXXV Međunarodnog savetovanja ENERGETIKA 2020 - Zbornik radova

Izdavač:	Savez energetičara Bulevar kralja Aleksandra 73, 11020 Beograd E-mail: info@savezenergeticara.org www.savezenergeticara.org
Glavni i odgovorni urednik:	Prof. dr Nikola Rajaković
Priprema i tehnička obrada:	BBN Congress Management d.o.o.
Produkcija:	NT Company
Tiraž:	150
Godina izdavanja:	2020.

CIP - Каталогизација у публикацији
Народна библиотека Србије, Београд

621.31(082)(0.034.2)
502.131.1:620.9(082)(0.034.2)
338.4:621.31(082)(0.034.2)

МЕЂУНАРОДНО саветовање Енергетика (35 ; 2020 ; Златибор)
Zbornik radova [Elektronski izvor] = Conference proceedings : XXXV Međunarodno savetovanje u organizaciji Saveza energetičara Energetika 2020 : 24-27. jun 2020. godine, Zlatibor / [glavni i odgovorni urednik] Nikola Rajaković. - Beograd : Savez energetičara, 2020 (Beograd : NT Company). - 1 elektronski optički disk (CD-ROM) ; 12 cm. - (Energija, ekonomija, ekologija, ISSN 0354-8651)

Sistemski zahtevi: Nisu navedeni. - Radovi na više jezika. - Nasl. sa naslovne strane dokumenta. - Tiraž 150. - Napomene i bibliografske reference uz tekst. - Bibliografija uz svaki rad. - Abstracts.

ISBN 978-86-86199-02-7

а) Електроенергетика -- Зборници б) Енергетска политика -- Зборници в) Енергетски извори -- Одрживи развој -- Зборници

COBISS.SR-ID 15460873

energija | ekonomija | ekologija

Sadržaj

Uvodno predavanje

MOGUĆI SCENARIJI RAZVOJA ENERGETSKOG SEKTORA REPUBLIKE SRBIJE 11
Miloš Banjac, Srbija

Tema 1 - Ekonomska i regulatorno-razvojna pitanja energetskog sektora

ANALIZA LEGISLATIVE KOJA UREĐUJE DJELATNOST SNABDIJEVANJA ELEKTRIČNOM ENERGIJOM U BOSNI I HERCEGOVINI IZ PERSPEKTIVE SNABDJEVAČA - JP ELEKTROPRIVREDA BIH 12
Meliha Džizić, Džemo Borovina, Elvedin Grabovica, Bosna i Hercegovina

ANALIZA MEĐUZAVISNOSTI POTROŠNJE ELEKTRIČNE ENERGIJE I RASTA BRUTO DOMAĆEG PROIZVODA U SRBIJI 19
Mileta Đurković, Vojin Grujić, Đorđe Ristić, Srbija

OCENA I RAZVOJ STRATEGIJA ZA ODRŽIVO ENERGETSKO PLANIRANJE U SRBIJI PRIMENOM SWOT-AHP METODOLOGIJE 24
Bojan Stojčetović, Živče Šarkoćević, Dragan Lazarević, Jasmina Dedić, Srbija

ZELENA EKONOMIJA I DUGOROČNA STRATEGIJA RAZVOJA ENERGETIKE 30
Gordana Kokeza, Srbija

METODOLOGIJA ZA PRIORITIZACIJU INVESTICIONIH PROJEKATA 35
Miljan Žikić, Vladan Ristić, Vojislav Simović, Srbija

NAJVEĆI IZAZOVI ENERGETSKE TRANZICIJE U SRBIJI: U SREDNJEM I DUGOM ROKU 40
Petar Đukić, Slaviša Đukanović, Srbija

UPRAVLJANJE LJUDSKIM RESURSIMA U ENERGETSKIM KOMPANIJAMA – PRIMER KOMPANIJE ROSETI (RUSIJA) 46
Aleksandar Latinović, Jovana Petrović, Dragan Surudžić, Dušan Marinković, Jelena Drašković, Uroš Rajović, Milan Vuksan, Isidora Ljumović, Srbija

ISTRAŽIVANJE MOGUĆIH SCENARIJA ENERGETSKE BUDUĆNOSTI REPUBLIKE SRBIJE UZ POMOĆ BACKCASTING METHODOLOGY I SOFTVERA ENERGOVIZIJA MB 51
Milun Babić, Srbija

PROJEKTI SOLARNIH FOTONAPONSKIH SISTEMA U INDUSTRIJI 60
Miodrag Vuković, Aca Jovanović

Tema 2 - Elektroenergetske mreže i tržišta u energetici

REKONFIGURACIJA I OTOČNA KOMPENZACIJA DISTRIBUTIVNE MREŽE U SVRHU SMANJENJA GUBITAKA NA ELEKTRIČNU ENERGIJU 65
Branko Stojanović, Tomislav Rajić, Srbija

STOHASTIČKA ANALIZA RADA I RAZVOJA ELEKTROENERGETSKOG SISTEMA SRBIJE 73
Đorđe Lazović, Aleksandar Savić, Mileta Žarković, Kristina Džodić, Srbija

UTICAJ GREŠKE PRENOSNOG ODNOSA ENERGETSKOG TRANSFORMATORA NA ODREĐIVANJE POLOŽAJA REGULACIONE PREKLOPKE IZ STRUJA I NAPONA PRIMARA I SEKUNDARA 81
Siniša Spremić, Dušan Obradović, Srbija

VOĐENJE PODATAKA O POUZDANOSTI ELEKTRODISTRIBUTIVNE MREŽE U ED KRAGUJEVAC 86
Miroslav Domanović, Biljana Janković, Srbija

ANALIZA STANJA SISTEMA ZAŠTITE NA OBJEKTIMA ELEKTRANA SRBIJE I REPUBLIKE SRPSKE I SMERNICE ZA UNAPREĐENJE PODEŠENJA 91
Milorad Zakić, Miljana Todorović, Srbija

UPOTREBA NOVIH TEHNOLOGIJA U UPRAVLJANJU DISTRIBUTIVNIM ELEKTROENERGETSKIM SISTEMOM 100
Milica Porobić, Sonja Nikolić, Gordana Jovanović, Ratko Rogan, Milan Ogrizović, Srbija

ZAŠTITA TRONAMOTAJNOG ENERGETSKOG TRANSFORMATORA ZASNOVANA NA FAZNOJ KOMPARACIJI STRUJA 106
Jelisaveta Krstivojević, Zoran Stojanović, Milenko Đurić, Srbija

ANALIZA IZVODLJIVOSTI JAVNOG OSVETLJENJA GRADA KRAGUJEVCA PRIMENOM RAZLIČITIH SVETLOSNIH IZVORA 113
Zoran Kovačević, Marija Mladenović, Srbija

PROBLEMATIKA PRIKLJUČENJA VETROELEKTRANA NA PRENOSNU MREŽU EMS AD 118
Saša Zdravković, Milan Blažić, Branko Šumonja, Marija Đorđević, Julijana Vićovac, Nebojša Đurin, Srbija
ANALIZA UTICAJA INTEROPERABILNOSTI NA TROŠKOVE UVOĐENJA SISTEMA ZA DALJINSKO OČITAVANJE BROJILA I UPRAVLJANJE POTROŠNJOM 124
Jovan Vujasinović, Goran Savić, Nikola Rajaković, Srbija
IMPLEMENTACIJA ALGORITMA KOLONIJE MRAVA ZA OPTIMALNU REKONFIGURACIJU DISTRIBUTIVNE MREŽE 128
Predrag Mršić, Bosna i Hercegovina, Nikola Rajaković, Srbija
ANALIZA ZAGREVANJA BAKARNIH PROVODNIKA SA STRUJOM 136
Karolina Kasaš-Lažetić, Gorana Mijatović, Dejana Herceg, Miroslav Prša, Srbija
UTICAJ ARMIRANO BETONSKOG STUBA NA RASPODELU MAGNETSKOG POLJA MEŠOVITOG VODA 142
Teodora Gavrilov, Karolina Kasaš-Lažetić, Kristian Haška, Miroslav Prša, Srbija
PRORAČUN EKVIVALENTNOG VREMENA TRAJANJA GUBITAKA NA OSNOVU IZMERENIH ISTORIJSKIH VREDNOSTI 149
Vojislav Simović, Vladan Ristić, Miljan Žikić, Ivan Trkulja, Srbija
POBOLJŠANJE KVALITETA ISPORUKE ELEKTRIČNE ENERGIJE OPŠTINE OBRENOVAC U PERIODU 2016.-2018. 154
Aleksandar Milojković, Dragan Milenković, Srbija
BRZA REGULACIJA FREKVENCIJE U SISTEMIMA MALE INERCIJE 160
Jelena Stojković, Predrag Stefanov, Srbija
PRIMENA GIS REZULTATA I GIS ANALIZE NAKON PRIKUPLJENIH TERENSKIH PODATAKA O DISTRIBUTIVNOJ MREŽI NA PRIMERU OGRANKA MLADENOVAC 166
Vladimir Stojičić, Srbija

Tema 3 - Energetska efikasnost (domaćinstva, komunalni sektor, industrija, zgradarstvo, …

LABORATORIJSKIM ISTRAŽIVANJEM DO IZBORA MJESTA UVOĐENJA STEPENOVANOG VAZDUHA ZA SAGORIJEVANJE U LOŽIŠTE 174
Nihad Hodžić, Anes Kazagić, Kenan Kadić, Bosna i Hercegovina
POBOLJŠANJE ENERGETSKE EFIKASNOSTI INDUSTRIJSKE GASNE PEĆI KORIŠĆENJEM SISTEMA PONOVNE UPOTREBE TOPLOTE 181
Vlatko Cingoski, Sašo Gelev, Zoran Kocevski, Republika Severna Makedonija
TOPLOTNO BILANSIRANJE I POVEĆANJE EFIKASNOSTI KORIŠĆENJA TOPLOTNE ENERGIJE VRTIĆA „ZEKA“ U GRADU KRAGUJEVCU, SRBIJA 187
Davor Jovanović, Dušan Gordić, Jelena Nikolić, Mladen Josijević, Nebojša Jurišević, Srbija
REKONSTRUKCIJA ELEKTROMOTORNOG POGONA KOLICA TRANSPORTNIH TRAKA T5L I T5P U SISTEMU DOPREME UGLJA NA TERMOELEKTRANI „NIKOLA TESLA“-B 194
Željko V. Despotović, Aleksandar Ribić, Dejan Đokić, Ranko Rakijaš, Dušan Ivanić, Srbija
PREGLED MERA ENERGETSKE EFIKASNOSTI I SPROVOĐENJE ENERGETSKOG PREGLEDA U PREHRAMBENOJ INDUSTRIJI 203
Mladen Josijević, Vanja Šušteršič, Dušan Gordić, Vladimir Vukašinović, Danijela Nikolić, Nikola Rakić, Srbija
POBOLJŠAVANJE ENERGETSKE EFIKASNOSTI HIDRAULIČNIH SISTEMA KOD TEŠKIH MAŠINA 209
Emil Zaev, Darko Babunski, Laze Trajkovski, Dejvid Anastasovski, Republika Severna Makedonija, Gerhard Rath, Austrija
OTPADNI GAS KAO ENERGENT – POVEĆANJE ENERGETSKE EFIKASNOSTI U SKLADU SA STRATEGIJOM RAZVOJA HIP-PETROHEMIJE 217
Siniša Petrić, Biljana Suslov, Srbija
ISPITIVANJE ENERGETSKE EFKASNOSTI U DOMAĆINSTVIMA NA TERITORIJI GRADA NOVOG SADA 222
Ivona Cokić, Aleksandra Ivanović, Srbija
PRIMJENA RC-MODELA U SIMULACIJI DINAMIČKIH PROCESA RAZMJENE TOPLOTE GRAĐEVINSKIH OBJEKTA SA OKRUŽENJEM 228
Svetlana Dumonjić-Milovanović, Petar Gvero, Zdravko Milovanović, Bosna i Hercegovina
SISTEM MENADŽMENTA ENERGIJOM HIP-PETROHEMIJA PANČEVO 234
Biljana Suslov, Miša Bulajić, Srbija

Tema 4 - Nove tehnologije u energetici

LABORATORIJSKIM ISTRAŽIVANJEM PULSIRAJUĆEG SAGORIJEVANJA DO NOVIH TEHNOLOGIJA U TERMOENERGETICI 238
Nihad Hodžić, Sađit Metović, Bosna i Hercegovina
OPTIMIZACIJA KONCENTRATORA VAZDUHA VETROTURBINA SA VERTIKALNOM OSOM OBRTANJA 244
Ognjen Peković, Jelena Svorcan, Aleksandar Simonović, Toni Ivanov, Dragoljub Tanović, Srbija
ISPITIVANJE MEHANIČKIH KARAKTERISTIKA KOMPOZITNIH PLOČA NA ISTEZANJE 250
Marija Baltić, Mohammad Sakib Hasan, David Daou, Aleksa Milovanović, Aleksandar Kovačević, Miloš Milošević, Srbija
OTKRIVANJE I ANALIZA SIGNALA PARCIJALNIH PRAŽNJENJA U ENERGETSKOM TRANSFORMATORU UHF METODOM 256
Đorđe Dukanac, Srbija
NUMERIČKA STRUKTURALNA ANALIZA KOMPOZITNE LOPATICE VETROTURBINE ... 262
Milica Milić, Jelena Svorcan, Vladimir Jazarević, Srbija
MODIFIKACIJA MODELA HIDROELEKTRIČNE CENTRALE PREKO IZMERENIH ODZIVA REALNE CENTRALE 267
Darko Babunski, Pance Bogoevski, Emil Zaev, Atanasko Tuneski, Republika Severna Makedonija
RAZVOJ PROPELERSKE TURBINE SA PROMENLJIVOM BRZINOM ZA PIKO HIDROELEKTRANE 272
Filip Stojkovski, Slovenija, Valentino Stojkovski, Republika Severna Makedonija
OPTIMIZACIJSKI MODEL ZA ODREĐIVANJE PARAMETARA EKSPLOATACIJE TURBINA KOD HEC SA VIŠE AGREGATA 278
Zvonimir Kostikj, Jovan Adamovski, Vojo Atanasovski, Jovan Stefanovski, Valentino Stojkovski, Republika Severna Makedonija
ODNOS INOKULUM/SUPSTRAT: PRORAČUNSKE METODE 285
Nikola Rakić, Vanja Šušteršič, Dušan Gordić, Mladen Josijević, Nebojša Jurišević (Srbija), Jelena Nikolić, Srbija
NEKI ASPEKTI PRIMENE HERMETIČKI ZAPTIVENIH TRANSFORMATORA 20(10)/0,4 KV U DISTRIBUTIVNOJ MREŽI SRBIJE 292
Vladimir Ostraćanin, Veljko Jovanović, Radomir Todorović, Novica Knežević, Nenad Janković, Srbija
ANALIZA RAZLOGA NASTANKA PUKOTINA NA CEVOVODU JELOVSKI SIFON 297
Aleksandar Levkoski, Valentino Stojkovski, Darko Mickoski, Republika Severna Makedonija
IZAZOVI U PROJEKTOVANJU I MONTAŽI HIDROMEHANIČKE OPREME VELIKIH RAZMERA 305
Filip Stojkovski, Sašo Belšak, Robert Broz, Slovenija
FRANCIS TURBINE S PROMJENJIVOM BRZINOM U MALIM HIDROELEKTRANAMA: MOGUĆNOSTI I IZAZOVI 312
Filip Stojkovski, Slovenija, Marija Lazarevikj, Valentino Stojkovski, Zoran Markov, Republika Severna Makedonija
STRATEGIJA ZA REVITALIZACIJU OPREME MHE SA EFEKTIMA ZA POVEĆANJE ENERGETSKE EFIKASNOSTI HS STREZEVO 318
Jovan Adamovski, Metodija Gramatkovski, Dame Korunoski, Valentino Stojkovski, Republika Severna Makedonija
ANALIZA ALGORITAMA ZA KOMPENZACIJU ZASIĆENJA STRUJNOG TRANSFORMATORA 324
Nenad Belčević, Zoran Stojanović, Srbija
PRIMENA SOFTVERSKOG ALATA XGSLAB ZA PRORAČUN ELEKTROMAGNETSKOG POLJA U BLIZINI DALEKOVODA 331
Dragutin Salamon, Jovan Mikulović, Tomislav Rajić, Srbija
INCIDENTI U INFORMACIONO-KOMUNIKACIONIM SISTEMIMA U ENERGETICI 337
Zdravko Ristić, Duško Ralić, Srbija
MOGUĆNOSTI UPOTREBE REZNICA MALINE I KUPINE ZA PROIZVODNJU: PELETA, BRIKETA, TERMO-ZVUČNE IZOLACIONE PLOČE I KOMPOSTA 345
Srećko Ćurčić, Sandra Milunović Koprivica, Milan Vesković, Srbija
HIBRIDNO NAPAJANJE TELEKOMUNIKACIONE I MERNE OPREME DALJINSKIH MERNIH STANICA U SISTEMIMA ZAŠTITE OD POPLAVA 350
Željko V. Despotović, Marko Tajdić, Jovan Kon, Srbija
SANACIJA OŠTEĆENJA VRATILA I LOPATICA VENTILACIONOG PRSTENA GENERATORA AGREGATA NA HIDROELEKTRANI 360
Miodrag Arsić, Vencislav Grabulov, Mladen Mladenović, Srđan Bulatović, Zoran Savić, Srbija
SANACIJE OŠTEĆENIH POVRŠINA RUKAVACA I ZAVARENIH OBLOGA LOPATICA USMERNOG APARATA NA HIDROELEKTRANI ĐERDAP 1 364
Miodrag Arsić, Srđan Bošnjak, Vencislav Grabulov, Mladen Mladenović, Dušan Arsić, Srbija

energija | ekonomija | ekologija

Tema 5 – Obnovljivi izvori energije (sunce, vetar, voda biomasa, biogas, geotermalna energija,...)

SKLADIŠTENJE ELEKTRIČNE ENERGIJE U NISKONAPONSKOJ DISTRIBUTIVNOJ MREŽI SA FOTONAPONSKIM ELEKTRANAMA 369
Sakib Jusić, Bosna i Hercegovina

ENERGETSKO - EKONOMSKA ANALIZA RADA VETROELEKTRANA U SRBIJI SA ASPEKTA JP EPS 377
Nikola Milićević, Vladimir Brković, Srbija

PROJEKTOVANJE MODELA OPTIMALNOG UPRAVLJANJA SA KASKADNO POVEZANIM HIDROELEKTRANAMA 382
Darko Babunski, Sašo Spasovski, Emil Zaev, Atanasko Tuneski, Republika Severna Makedonija

SKRIVENI HIDROENERGETSKI POTENCIJAL U SISTEMU HEC VRBEN 388
Ejup Bekiri, Valentino Stojkovski, Stojče Ilieski, Republika Severna Makedonija

ANALIZA KAPACITETA I USLOVA IZGRADNJE FOTONAPONSKIH SISTEMA NA KROVOVIMA ŠKOLSKIH OBJEKTA U SRBIJI 394
Iva Batić, Željko Đurišić, Srbija

NAPAJANJE STAMBENOG OBJEKTA POMOĆU OBNOVLJIVIH IZVORA ENERGIJE PRIMJENOM PROGRAMA HOMER 402
Velemir Gavrilović, Bosna i Hercegovina

ZAMENA IZOLACIONIH ULOŽAKA NA STATORU SINHRONOG GENERATORA U HIDROELEKTRANI POTPEĆ 409
Predrag Mlađenović, Predrag Šaponjić, Srbija

KORIŠĆENJE ALATA ZA TRŽIŠNO MODELOVANJE PRI ANALIZI BENEFITA PO ELEKTROENERGETSKI SISTEM IZGRADNJOM NOVOG INTERKONEKTIVNOG DALEKOVODA 414
Srđan Bošković, Srbija

FOTONAPONSKE ELEKTRANE SA MODULIMA SA DVOSTRANIM AKTIVNIM POVRŠINAMA 420
Vladan Durković, Crna Gora, Željko Đurišić, Srbija

TEHNOEKONOMSKA ANALIZA PROIZVODNJE BRIKETA I PELETA 427
Sandra Milunović Koprivica, Ivan Lapčević, Srećko Ćurčić, Srbija

UPOREDNA TERMODINAMIČKA ANALIZA ORGANSKOG RANKINOVOG I KALINA CIKLUSA 434
Miloš Banjac, Srbija

UTICAJ SOLARNE ELEKTRANE NA KVALITET ELEKTRIČNE ENERGIJE U NISKONAPONSKOJ DISTRIBUTIVNOJ MREŽI 440
Hidajet Salkić, Amir Softić, Amer Salkić, Bosna i Hercegovina

PRIMENA GIS-A I FUZZY LOGIKE U EVALUACIJI POGODNIH LOKACIJA ZA SOLARNE PARKOVE 449
Ljubomir Gigović, Zlate Veličković, Zoran Bajić, Srbija

PROVERA TEHNIČKIH PARAMETARA GENERATORA I BLOK-TRANSFORMATORA ZA POTREBE UKLAPANJA HE KOMARNICA U EES CRNE GORE 456
Brankica Popović Zdravković, Zoran Popović, Srbija

PRIMENA LAGRANŽOVE OPTIMIZACIJE NA PROBLEMATIKU PROIZVODNJE ENERGIJE IZ OBNOVLJIVIH IZVORA 463
Vladan Ristić, Nikola Rajaković, Srbija

ANALIZA MOGUĆIH EFEKATA REGULACIJE REAKTIVNIH SNAGA U PERSPEKTIVNIM VETROELEKTRANAMA NA NAPONSKE PRILIKE I GUBITKE U PRENOSNOJ MREŽI SRBIJE 472
Milica Koprivica, Ivana Stamenić, Željko Đurišić, Srbija

OPERATIVNI REŽIM RADA HIDROELEKTRANA U KASKADNOM SISTEMU ZAVISNO OD POTREBE ENERGETSKOG SISTEMA 478
Sofija Nikolova Poceva, Anton Chaushevski, Valentino Stojkovski, Zoran Markov, Republika Severna Makedonija

DEKARBONIZACIJA TRANSPORTNOG SEKTORA KROZ INTEGRACIJU FOTONAPONSKIH SISTEMA I ELEKTRIČNIH VOZILA 485
Đorđe Lazović, Bojana Škrbić, Kristina Džodić, Željko Đurišić, Srbija

UTICAJ VETROPARKOVA NA ŽIVOTNU SREDINU 493
Nada Curović, Nebojša Petrović, Ivan Milanov, Srbija

PREDIKCIJA INTENZITETA GLOBALNOG SUNČEVOG ZRAČENJA PRIMENOM VEŠTAČKIH NEURONSKIH MREŽA 500
Milan Marjanović, Nedeljko Dučić, Vojislav Vujičić, Snežana Dragićević, Srbija

energija | ekonomija | ekologija

ELEKTRIČNI AUTOMOBILI SA INTEGRISANIM FOTONAPONSKIM SISTEMOM 505
Vladimir Antonijević, Željko Đurišić, Srbija
EKSPERIMENTALNO ISTRAZIVANJE KOEFICIJENTA PRITISKA AEROPROFILA U VAZDUSNI TUNEL 512
Borjan Janoski, Viktor Aleksoski, Marija Lazarevikj, Viktor Iliev, Makedonija

Tema 6 - Neobnovljivi izvori energije i nove tehnologije u energetici

ANALIZA VIBRACIJA NA STRELI KOPAČA UGLJA U SISTEMU NA DOPREMI UGLJA NA TERMOELEKTRANI „NIKOLA TESLA“-B 517
Željko V. Despotović, Aleksandar Ribić, Aleksandar Pavlović, Uroš Tanasić, Nenad Glišić, Srbija
ISKUSTVO I PREDNOSTI RADA KOMBINIRANE GASNE ELEKTRANE TE-TO AD SKOPLJE NA CENTRALNOM SISTEMU GREJANJA U GRADU SKOPLJU 524
Dejan Kitanovski, Hristo Kirovski, Gjorgi Karaliev, Republika Severna Makedonija
SIGURNOST SNABDEVANJA PRIRODNIM GASOM U REPUBLICI SRBIJI 529
Dejan Ivezić, Marija Živković, Srbija
ANALIZA SAVREMENIH SISTEMA ZA PRAĆENJE KVANTITATIVNOG STANJA DERIVATA NAFTE U SKLADIŠTU I TERENSKIM USLOVIMA 534
Darko Latinkić, Jovica Bogdanov, Radovan Karkalić, Mihael Bučko, Srbija
ISPITIVANJE ELEMENATA ZAŠTITE OD ATMOSFERSKOG PRAŽNJENJA UNAPREĐENIM METODAMA 539
Dejan Mojić, Daliborka Ilić, Srbija
VIBRO-MONITORING SISTEM ZA TURBINE, ILI BILO KOJE DRUGE ROTACIONE MAŠINE 546
Vladimir Nešić, Aleksa Srećković, Ognjen Ristić, Predrag Marić, Srbija
IMPLEMENTACIJA SISTEMA DOJAVE POŽARA NA LOKOMOTIVAMA ŽELEZNIČKOG TRANSPORTA U TENT-U 551
Nenad Jovanić, Dragana Miletić, Saša Trivić, Đorđe Babić, Srbija

Tema 7 - Multisektorski zadaci u oblasti unapređenja životne sredine na putu Republike Srbije prema EU

ENERGETSKO SIROMAŠTVO 557
Slavica Bardić, Hrvatska
ZELENI PRSTEN KAO METOD UNAPREĐENJA ŽIVOTNE SREDINE U JP EPS 563
Jovana Šejat, Sandra Stefanović, Tijana Starčević, Srbija
PRIMENA JEFTINOG ADSORBENTA NA BAZI LETEĆEG PEPELA ZA UKLANJANJE PESTICIDA IZ VODE 570
Zlate Veličković, Zoran Bajić, Aleksandar Marinković, Milica Karanac, Radovan Karkalić, Snežana Radić, Ljubomir Gigović, Srbija
OBNOVLJIVI IZVORI ENERGIJE - PRIMARNI MEHANIZAM ENERGETSKE POLITIKE EUROPSKE UNIJE 576
Milan Ivanović, Hrvoje Glavaš, Hrvatska
METODOLOGIJE ENERGETSKO – KLIMATSKOG PLANIRANJA ZAPADNOG BALKANA: NAJNOVIJA DOSTIGNUĆA IZ REPUBLIKE SRBIJE I BOSNE I HERCEGOVINE 582
Ilija Batas Bjelić, Nikola Rajaković, Srbija
SAJBER BEZBEDNOST U ENERGETSKOM SEKTORU 583
Biljana Trivić, Darko Šošić, Srbija
SMANJENJE EMISIJE NOX IZ BLOKA A4 TE NIKOLA TESLA – IMPLEMENTACIJA PROJEKTA FINANSIRANOG IZ SREDSTAVA EU IZ PERSPEKTIVE FIDIC INŽENJERA 590
Danila Stančević, Jasna Grujić, Srbija
ZAGAĐENJE ŽIVOTNE SREDINE I NAFTA I GAS 597
Sonja Ketin, Rade Biočanin, Mirjana Vojinović Miloradov, Marko Andrejić, Srbija

eee

Operativni režim rada hidroelektrana u kaskadnom sistemu zavisno od potrebe energetskog sistema

Hydro power plants operating modes in a cascade system depending on the needs of the power system

Sofija Nikolova Poceva[*], **Anton Chaushevski**[*], **Valentino Stojkovski**[**], **Zoran Markov**[**]

[*] University Sts Cyril and Methodius, Faculty of Electrical Engineering and Information Technology, Skopje, MKD
[**] University Sts Cyril and Methodius, Faculty of Mechanical Engineering, Skopje, MKD

Apstrakt - Rad prezentira model i metodologija za operativne režime rada hidroelektrana u kaskadnom povezani hidraulični sistem. To uključuje upravljanje vodom proizvodnih i/ili crpnih (pumpne) jedinice, uzimajući u obzir tehničke karakteristike postrojenja elektrana (turbine/generator i pumpe/motorni sistemi), karakteristike rezervoara uzimajući u obzir svu infrastrukturu koja je hidraulično povezana. Svakako tu spadaju i hidrološke prilike i uslove (prirodni priliv i priliv uzvodnih turbina), Cilj operativnih režima rada za hidroenergetske sisteme je imati maksimalan profit od proizvodnje električne energije uzimajući u obzir regionalno okruženje tržišta električne energije, potrebe elektroenergetskog sistema, kao i zadovoljenje tehničkih uslova i istovremeno izbegavanje preliva kolko je moguće. Načini rada hidroelektrana zavise od tržišne cene električne energije, tarifnim modelima i vremenetrajanja svake tarife (bazni, vršni i druge tarife), svakako uzevši u obzir tehničke karakteristike proizvodne jedinice, hidrotehničke uslove, količine akumulacionih rezervoara i drugi uslove. Primena modela će biti prezentovana sa rezultatima na stvarnim hidroenergetskim sistemima koji se sastoje od različiti hidraulični infrastrukturnih elemenata, za različite slučajevima koje zavise od hidroloških uslova i zahteva. Model se može koristiti za izradu preliminarne analize za tehničko poboljšanje hidro-sistema preko dodatnu instaliranu snagu postojećeg sistema. Izabrani rezultati sa analizama biće predstavljeni odgovarajućim upoređivanjem i na kraju sa zaključnim komentarima.

Ključne reči – proizvodnja, hidroelektrana, pumpa, revizibilna, turbina

Abstract- The paper presents the methodology for hydro power plants operation (Long-term and Short-term) in a hydro power cascade system. It includes water managing of generating and/or pumping units taking into accounts technical characteristics of the power plants facilities (turbine/generator and pump/motor systems), reservoirs characteristics considering all hydraulically connected infrastructures which are, as well as the hydrological conditions (for run offs and turbine inflows). The goal of the operation for all hydropower system is to have maximum profit from electricity production taking into account electricity market environment, power system requirements, as well as satisfying technical conditions and at the same time avoiding water spilling as it is maximum possible. Operating modes of the hydro power plants depend on electricity market price, tariff prices and time duration of each tariff (base, peak, and rush hour), technical characteristics of the unit(s), hydro technical conditions, water reservoir's volumes, run off and others.
The application of the model is presented with the results on real hydro power systems consist of different hydraulic connections in various cases depend on hydrological conditions and requirements. The model can be used to make preliminary analysis for additional improvement of hydro systems as having the results for additional installed power of the existing system. The selected output results are presented with appropriated comparing and at the end with conclusion remarks.

Index Terms- generation, hydro, pump, reversible, turbine

I. INTRODUCTION

The paper presents the model for different operation modes of hydraulically connected hydropower system (HPS) consists of reservoirs, pipe connected lines and hydro power plants. The operating modes can be distinguished depend time interval planning (year, season or month for Long Term (LT) and week, few days or a day for Short Term (ST)). The model takes into account the technical specifications and parameters of the whole system such as:

- Volume of the water reservoirs with limitation of minimal and maximum elevation of the reservoirs,
- Turbine units characteristics (flows, power),
- Other technical constraints and specifications of the elements of the hydropower system,
- Connected infrastructure of lines and pipes,

The application of the model is done on the real hydropower system on river Crn Drim, taking into account the existing power system as well as the other reservoirs and power generation units in new HPPs which are considering to be built in next period.

II. DESCRIPTION OF THE MODEL

The model gives main outputs of hydropower system depend on power system operator requirements and demand, as well as taking into account input of water run offs with respecting the technical conditions of the system. The modeling approaches depend on LT or ST operation modes. In the LT operation modes, the whole considering time period (T) can be a year or few years dividing on months' or weeks' time intervals (t) (depend on availability of hydrological data) and mainly considering the large reservoirs. In the ST operation modes, the whole considering time period (T) can be a week or few days dividing on hourly intervals (t) and mainly taking into account the water management for small reservoirs in daily regulation. The output results from the model are turbine discharges, electricity production of HPPs as well as reservoir level for each time interval (t) of whole considering time period T. In order to simulate the operation regimes of the whole system, it is necessary to know the characteristics of the reservoirs. Modeling of the characteristic of the all reservoirs is done according [4] as two functions, volume dependence of the attitude (1) and vice versa, the attitude dependence of the volume (2).

$$\mathrm{Vol(Att)} = 2 \cdot \pi \cdot (A + B \cdot \mathrm{Att} + C \cdot \mathrm{Att}^2) \qquad (1)$$

$$\mathrm{Att(Vol)} = g + h \cdot (\mathrm{Vol} - d)^e \qquad (2)$$

The simulations of the operating regimes has been done taking into account the characteristics of the reservoirs, the water inflows and the turbine characteristics of the HPPs. The inputs in the model are the following: average inflows and run offs for the time intervals, the characteristic of the electric power output P=f (Q_{tur}, H_{gross}) as a function of turbine flow (Q_{tur}) and gross head and the reservoirs characteristics according (1) and (2). For financial analysis it is necessary to have the electricity prices. The following conditions and assumptions are taking into accounts in the model:

- The reservoirs level to be within the allowed limits and avoiding spilling.
- The turbine flow priority is to have maximum revenue from generated electricity according to the electricity market prices for each period of the day.

The output results from the calculations are the following ones:
-Consumed water volume in each time period (year, month, day,…) for each reservoir
-Output power for each time period P(t)
-Electricity generated for each time period W(t)
-Financial profit from the sold electricity FIN
The methodology for operation modes of hydro power plants can be applied in different needs depend on input data and the requirements from the utility or operator of the power plant. Some of the possible application can be done for:
Hydro power systems from simple to complex technical hydraulically configuration and connectivity for different time period of consideration (T) as: few years, a year, season, week, only a day. The period of consideration can be divided on different time intervals Δti, where $T = \sum_{i=1}^{n} \Delta t_i$

III. HYDEO POWER STSTEM OF CRN DRIM

The existing hydropower system (HPS) of river Crn Drim consists of 2 hydro power plants (HPP Globocica 2x21 MW and full turbine discharge of 50 m^3/s) and HPP Spilje (3x28MW and full turbine discharge of 108 m^3/s), three reservoirs (RES 1-Ohrid lake, RES 2 - Globocica and RES 3 - Debar lake) with main run offs from two rivers (Crn Drim and Radika). HPP Globocica with two units is the first upper stream power plant in HPS Crn Drim is a derivative power plant that uses the water from RES 1 of Lake Ohrid. Each of the two units is 25 m^3/s or total of 50 m^3/s, with a total installed capacity of 42 MW, have gross head of 108-110 m. The turbine flow from HPP Globocica and the Radika River are the main run offs for RES 3 of Debar Lake as the reservoir of HPP Spilje. Existing HPP Spilje has 3 units, each of 36 m^3/s or total of 108 m^3/s, with gross head of 80-100 m, and total installed capacity of 84 MW. Figure 1 schematically presents the existing HPS of Crn Drim with planned new hydro power plants and new RES 4.

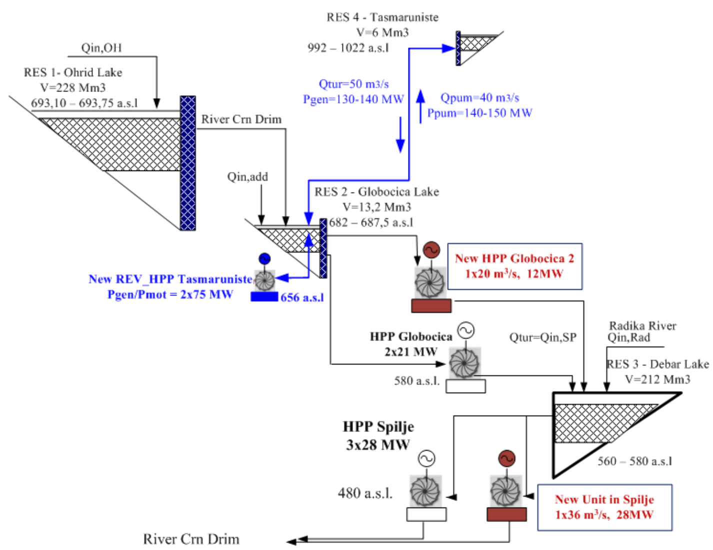

Figure 1. Hydraulically connected HPS of Crn Drim (existing and new reservoirs and units)

The new generating units are in HPP Globocica 2 with a unit of 20 m^3/s turbine flow and 12 MW installed power, located in new turbine hall with 70 m gross head. The additional unit in HPP Spilje has 36 m^3/s turbine flow and 28 MW installed power the same as the existing ones and located in the same turbine hall [1]. The new reversible (pump storage) HPP Tasmaruniste is added with the upper reservoir RES 4 Tasmaruniste on the Crn Drim system. The others basic technical parameters (from [2] and [3]) as the reservoirs' volumes, attitudes of the turbines, minimum and maximum reservoir levels, turbine flows and installed power are given on the Figure 1. Therefore the whole hydropower system which is considered in this paper, consists of 4 reservoirs with basic information given in Tab.1 and few HPPs with some technical characteristics given on Tab.2.

Table 1. Characteristics of the reservoirs of HPS Crn Drim

	Existing RES1	Existing RES2	Existing RES3	New RES4
Att.max (a.s.l.)	693.75	687.5	580	1022
Att.min (a.s.l.)	693.10	682	560	992
Vol. (10^6 m^3)	228.00	13.20	212.00	6.00

Table 2. HPPs Characteristics in HPS of Crn Drim

	No. of units	Q_{inst} (m^3/s)	H_{gross} (m)	P_{inst} (MW)
Exist.HPP Spilje	3	108	75-95	84
Exist. HPP Globoc.	2	50	102-105	42
New HPP Spilje 4 unit	1	36	75-95	28
New HPP Globoc. 2	1	20	70	12
New RevHPP Tasmar.	2	Qt=50, Qp=40	305-335	150

The Large reservoirs, RES 1 of Lake Ohrid and RES 3 of Debar Lake are important for long-term analyzes (seasonal, annual and multi-year). The small reservoir RES 2 of Globocica and RES 4 of Tasmarunista can be taken in short-term analyzes as daily, few days or weekly analyzes. The parameters according the formulas (1) and (2) for all reservoirs are given in Tab.3.

Table 3. The parameters for all reservoirs according (1) and (2).

	A	B	C	g	d	h	e
RES 1	1639724	-4863	3,60	675	-3136	0,3	0,5
RES 2	4135	-13	0,01	640	-48	6,1	0,5
RES 3	5790	-23	0,02	500	-194	4	0,5
RES 4	996	-2	0,001	971	-1,2	19	0,5

A. Long term (LT) operation modes of HPS Crn Drim

The simulations for HPS of Crn Drim for LT operation modes are made on the monthly basis time interval (t=1 month) in the whole period of a year (T= 1 year). The main idea of the simulation is to find the operational regimes with maximum financial benefit under new market conditions with electricity prices on the open market with different tariffs (Fig.2).

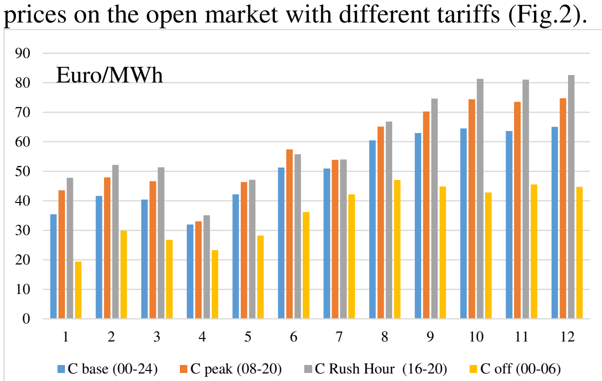

Fig. 2. Daily tariffs and electricity price C (€/MWh) from the HUPEX in 2018

The time periods for each day are divided into 2 groups (tariffs) for Long-term operation modes (Base tariff (C_{base}) and Peak tariff (C_{peak})). The water inflow for HPP Globocica (Qin,GL) is predominantly from Lake of Ohrid (Qin,OH), and the additional run offs ($Q_{in,add}$):

$$Q_{in,GL}(t) = Q_{in,OH}(t) + Q_{in,add}(t) \quad (3)$$

The water inflow for HPP Spilje ($Q_{in,SP}$) mainly depends on the turbine flow of HPP Globocica ($Q_{tur,GL}$) and the natural run off from Radika River ($Q_{in,Rad}$):

$$Q_{in,SP}(t) = Q_{tur,GL}(t) + Q_{in,Rad}(t) \quad (4)$$

According to natural flows from the input hydrological data [2], three characteristic hydrological years have been selected in yearly operating modes: 2001 as dry year representative, 2006 as average year representative and 2013 as wet year representative. Fig.3 and Fig.4 show the monthly water inflows for the reservoirs in HPP Globocica and HPP Spilje respectively, in each of the representative year.

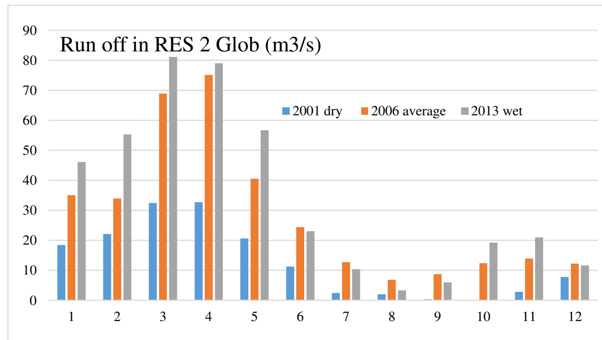

Figure 3. Monthly water inflows for the RES 2 of Ohrid

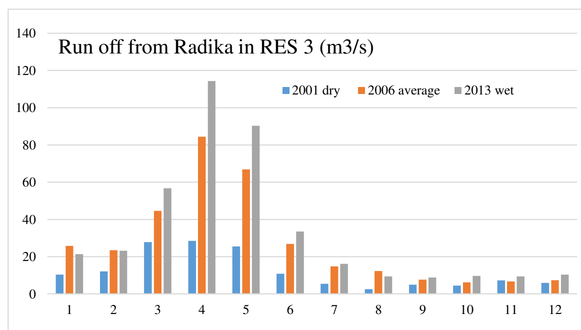

Figure 4. Monthly water inflows for the RES 3 of Debar Lake from Radika River

The starting value of the reservoirs level in 1st of January is common for all simulations, for Ohrid Lake is 693.3 a.s.l., and for Debar Lake is 563 a.s.l. The simulations are made for three years, dry 2001, average 2006 and wet 2013. The results for the representative of wet year are presented on Fig.5 and Fig.38 as the reservoirs level and the spent volume of water for HPP Globocica (dV_GL) and HPP Spilje (dV_SP) respectively.

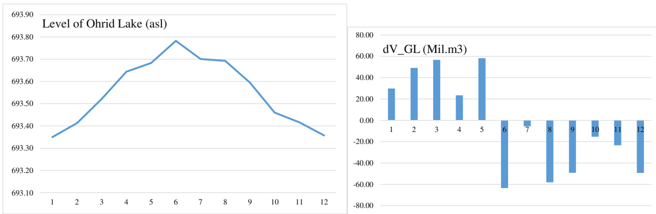

Figure 5. Reservoir level of Ohrid Lake and spent volume of water in HPP Globocica for each month in wet 2013

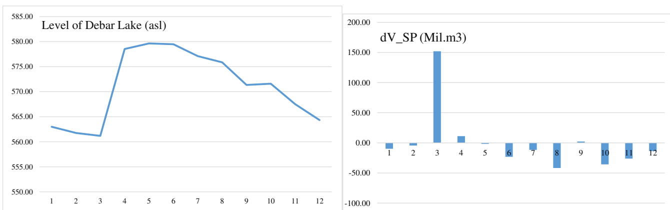

Figure 6. Reservoir level of Debar Lake and spent volume of water in HPP Spilje for each month in wet 2013

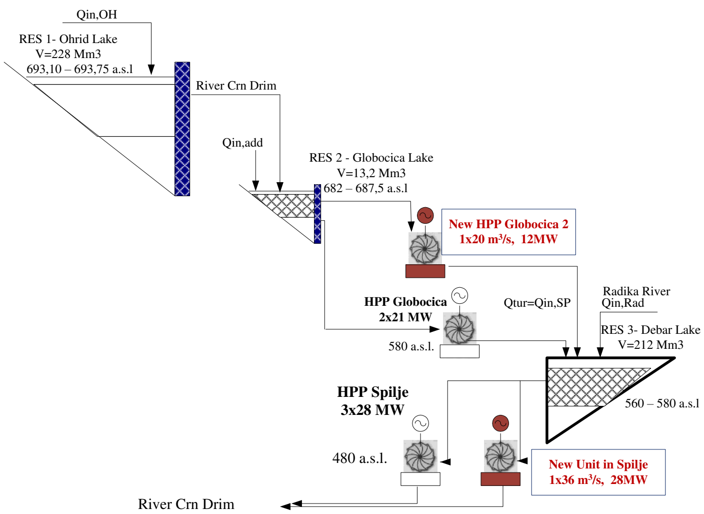

Figure 7. HPS considering for long term (LT) operation modes

For LT operation modes, the reversible HPP Tasmuruniste is not considered, only the conventional HPP Spilje and HPP Globocica (Fig.7). In order to avoid overflowing and spilling, the operation with maximum installed turbine flow for both HPPs is in the first months. The total balance of the both HPPs in the HPS of Crn Drim in generated electricity and financial income from the sold electricity is given in Table 4. The total generated electricity consists of 2 parts, base and peak where the income comes from, and the third part is lost electricity (negative one) because spilling. Therefore, for wet 2013, the all HPPs in HPS Crn Drim give:

• Production of around 658 GWh with total electricity sales of approximately 34.3 million euros.

• Overflow (spillway) of about 36 GWh with a total loss of un-produced electricity of about 1.2 million euros.

Table 4. Generated electricity and financial income for the wet 2013 in case with existing and additional units in HPS Crn Drim

	Generated Electricity W(MWh)			Financial Income FIN (Mil.Euro)		
	base	peak	spill	base	peak	spill
1	0	39717	0	0,00	2,13	0,00
2	0	35525	0	0,00	2,09	0,00
3	31329	23489	0	1,27	1,52	0,00
4	90595	36202	-36202	2,89	1,67	-1,20
5	63037	15665	0	2,66	1,41	0,00
6	35456	27876	0	1,82	2,42	0,00
7	0	26575	0	0,00	1,43	0,00
8	0	43686	0	0,00	2,84	0,00
9	0	32167	0	0,00	2,26	0,00
10	0	33289	0	0,00	3,07	0,00
11	0	31409	0	0,00	3,06	0,00
12	0	31811	0	0,00	3,00	0,00
Sum	220417	377410	-36202	8,63	26,91	-1,20
Total		657990				34,35

Fig.8 gives graphical presentation of the generated electricity in each month for the whole HPS Crn Drim in the wet 2013. The lost electricity because spilling is negative (bellow the apices axis in month of April).

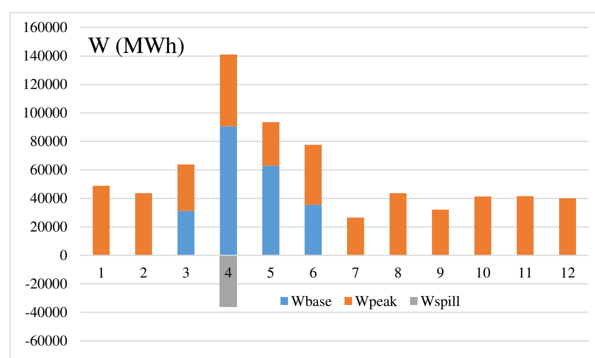

Figure 8. Monthly production for the HPS Crn Drim in wet 2013

According the calculation for all cases and for all representative years, the comparison of the results can be analyzed in order to have answer for the benefit of additional units installed of the HPS Crn Drim, which is very useful for further techno-economic analyzes. Tab.5 and Fig.9 show the generated electricity and lost energy in spilling, for all representative years.

Table 5. Generated electricity and spilled energy in MWh for all cases for HPS Crn Drim

	Dry 2001	Aver. 2006	Wet 2013
W_{base}	0	88440	220417
W_{peak}	194431	498460	473774
W_{spill}	0	0	-36202
Total	194431	586900	657990

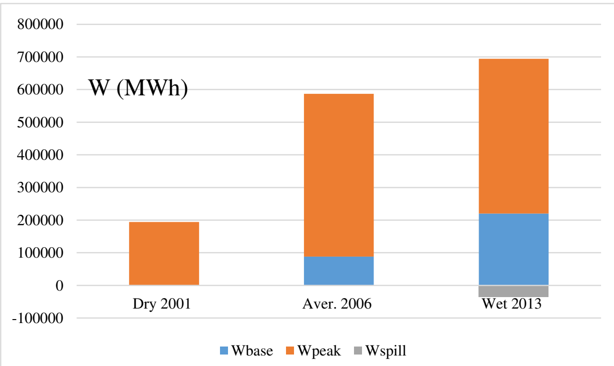

Figure 9. Comparing the output energy for all cases

The results show that the increased production and income can be got in additional units in peak tariffs with high prices. The other benefit of additional units is reducing the lost energy of spilling in wet 2013 to 36202 MWh, and the difference goes to additional peak electricity of the system. Tab.6 and Fig.10 give the benefit in Euro from income of generated electricity taking into account the lost energy of spilling.

Table 6. Financial benefit from income (in €) for all cases for HPS Crn Drim

	Dry 2001	Aver. 2006	Wet 2013
FIN_{base}	0	3866861	8634785
FIN_{peak}	10785275	28128836	26909732
FIN_{spill}	0	0	-1196258
Total	10785275	31995696	34348258

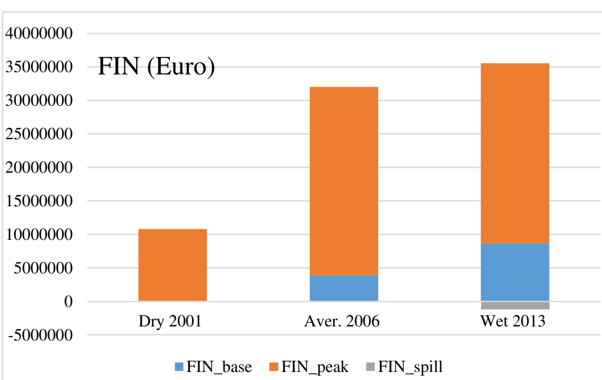

Figure 10. Comparing the income (in €) for all cases

The overall benefit for dry 2001 is approximately 10,5 M€, for average 2006 is approximately 32 M€ and for the wet 2013 is approximately 34,2 M€.

B. Short term (ST) operation modes of HPS Crn Drim

The simulation of ST operating modes for HPS of Crn Drim are done for some characteristics days , with the inputs taken from the LT results especially water inflows and turbine discharges. The main point in ST planning is focus on operation of reversible HPP Tasmaruniste with HPP Globocica (Fig.11), as well as the water managing between downstream RES 2 of Globocica and upstream RES 4 of Tasmarunista. The LT operation modes are made on the hourly time interval (t=1 hour) in the whole period of a year (T= 1 day/week…). In this simulations, within the day can be find the operation of turbine mode in the peak and/or rush hours (7-24 h) and pumping mode in off hours (0-6 h).

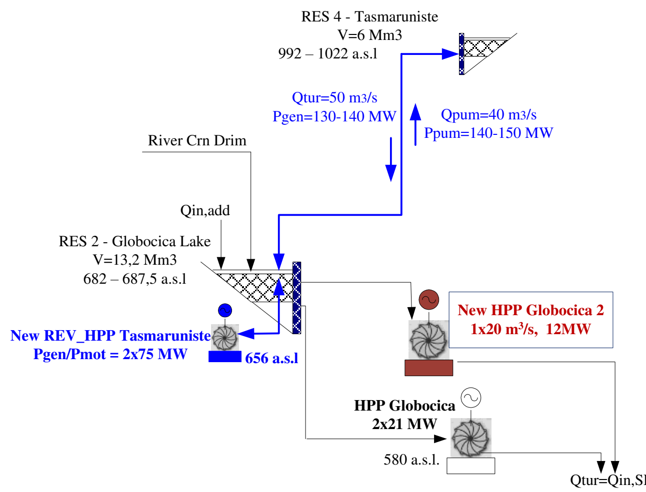

Figure 11. HPS considering for short term (ST) operation modes

According the Study [3], taking into account water losses and efficiencies of turbine and generator, the power output in (MW) injected to the grid in turbine-generation mode for Rev HPP is:

$$P_{gen}(t) = 8{,}35 \cdot Q_{tur}(t) \cdot H_{gross}(t) \qquad (5)$$

Also, taking into account water losses and efficiencies of pump and motor, the power in (MW) taken from the grid as consumer in pump-motor mode for Rev HPP is:

$$P_{mot}(t) = 11{,}58 \cdot Q_{pum}(t) \cdot H_{gross}(t) \qquad (6)$$

The time periods for each day are divided into hourly time intervals where for financial analysis it is taken 3 tariffs, night tariff (0-6h) - C_{off}, peak tariff (C_{peak}) and rush tariff (16-20h) (Crush). Fig.12 presents the turbine and pump flows in a day (24 hours) for reversible HPP Tasmarunista in a case of large inflow in RES 2-Globocuca Lake of Qin=32m3/s. The generated power (Fig.13) are from three HPPs (PL1-Globocica1, PL2-Globocica2, and Pg_TAS-Tasmaruniste). The power needs for pumping mode is Pp_TAS.

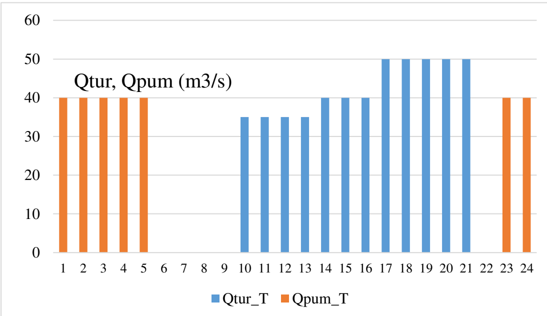

Figure 12. Turbine and pump flows for Rev. HPP Tasmaruniste

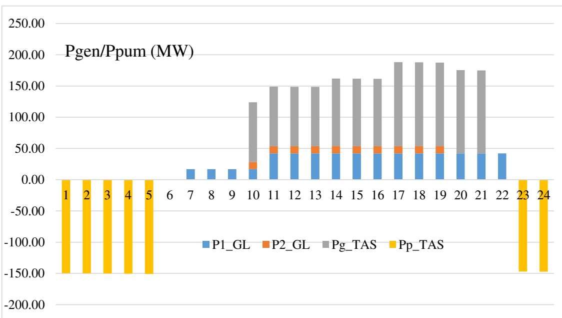

Figure 13. Generated and consumed power for the HPS on Fig.11

The graphs of the water level for upper RES2 – Globocica and downstream RES4 - Tasmarunista are given in Fig.14 and Fig.15

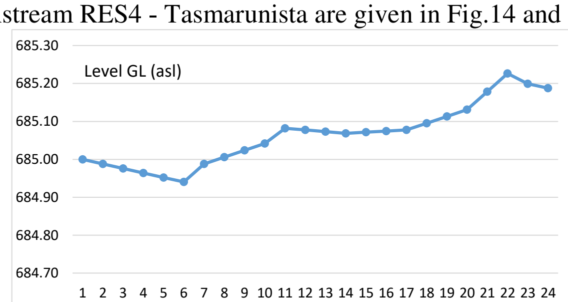

Figure 14. Water level for upper RES2 Globocica

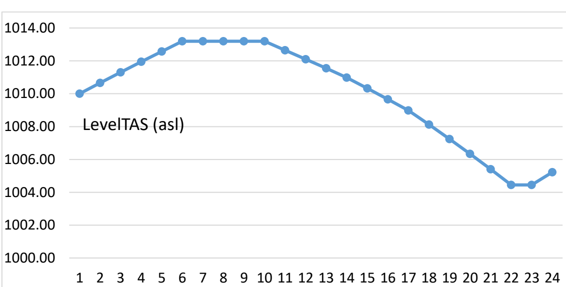

Figure 15. Water level for downstream RES4 Tasmarunista

The ratio between the volumes for pumping and for generation electricity is Vp/Vt=0,55 and for this amount of water, the ratio of the energies needed for pumping and generation is Wp/Wt=0,76.

The other LP simulation is done for 3 days (72 hours) operation mode for a low runoff for RES2 -Globocica Lake which is Qin=12m3/s, and the appropriated results are given on Fig.16 and Fig.17. The ratio between the volumes for pumping and for generation electricity is Vp/Vt=0,32, and for this amount of water, the ratio of the energies needed for pumping and generation is Wp/Wt=0,45.

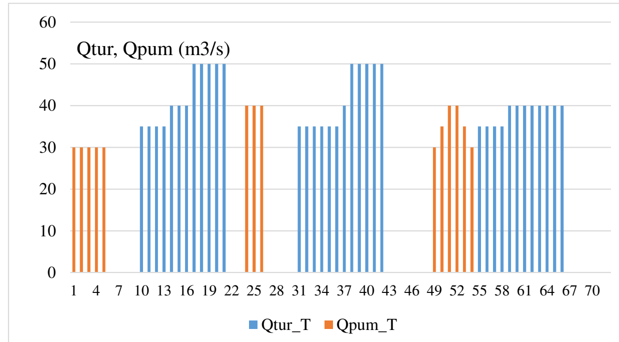

Figure 16. Turbine and pump flows for 3 days operation

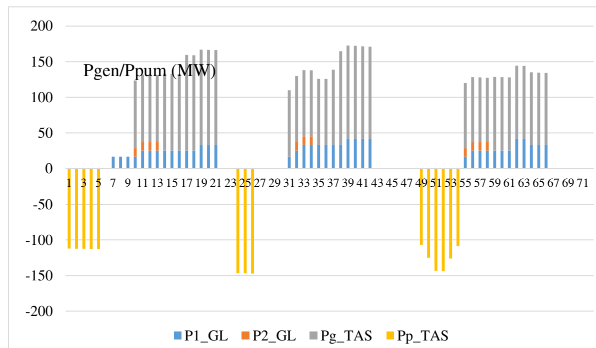

Figure 17. Generated and consumed power for 3 days operation

The operation mode in each time period of an hour, can be driven by the system operator requirements and electricity demand, but it should be taken the condition of minimum and maximum allowed levels for each reservoir of the system. The design of both reservoirs RES 2 and RES4 are enough for daily-weekly regulations in a system for installed turbine-pump flow of 50 m3/s. This case for ST operation modes does not include the operation mode of HPP Spilje which is down stream of the HPPs Globocica.

IV. CONCLUSION

The operating modes of the hydropower system depend on the turbine/pump and generator/motor installations for all units in conventional and/or reversible HPP, as well as depend on electricity needs and system operator requirements. Anyway, more units in the HPS means flexible operation of the whole system. For LT operation modes, it can be taken large reservoirs with conventional units, but depend on available data to have in the terms of hydrology (day, week, or month). For ST operation modes it can be taken the hourly operation for each power unit, with taken into consideration the reversible HPP. In this cases the flexible of the system can be improved in order to have maximum financial profit from electricity generation, but, it is possible for the prices when the ratio between peak tariff and low off tariff are large then the ratio between generated and pumped power for same amount of water or, when $C_{peak}/C_{off}>P_{gen}/P_{pum}$.

The benefits of complex hydropower system operation should be valorized in generated electricity, as well as financial benefit. Some of the additional analysis can be done, such as:

-Higher electricity production as a result of utilization of the overflow spilling water

-Engagement of the units in the periods of high tariffs per day, rather than production as a base plant.

-Opportunity for optimization of the whole system with all units in the HPS,

-Optimizing the HPS and avoid overflows, in order to obtain positive financial effects from the operation the entire hydro system

-Possibility for regulating the water flows of runoffs, as well as regulation of the reservoirs.

The main driven conditions for operation modes of the HPS depend on the complexity of the hydropower system from technical point of view (number of power units and reservoirs with their connectivity), as well as available hydrological data and operator or utility requirements.

REFERENCES

[1] GEING and FICHTNER , *Crn Drim River Basin, Study on Optimum Utilization of Hydropower Potential,* Final Report, April 2016.

[2] JSC ELEM, *Reports on Data for HPS of Crn Drim, HPP Globocica and HPP Spilje,* Skopje.

[3] Cakar and Partners, *Study for pump storage hydro power plant Tasmaruniste, made for ELEM*, Skopje 2010.

[4] VALORAGUA-A, *Model for the Optimal Operating Strategy of Mixed Hydrothermal Generating Systems*, 1992, IAEA, Vienna, Austria

[5] André Dozier, "Integrated Water and Power Modeling Framework for Renewable Energy Integration", *Colorado State University, Colorado, USA, 2012.*

AUTHORS

Sofija Nikolova Poceva – Associate Professor at Department of Power Plants and Power Systems, FEEIT, Skopje, nsofija@feit.ukim.edu.mk

Anton Chaushevski – Professor at Department of Power Plants and Power Systems, FEEIT, Skopje, caus@feit.ukim.edu.mk

Valentino Stojkovski – Professor at Department of Hydraulic Turbines, Faculty of Mechanical Engineering Skopje, valentino.stojkovski@mf.edu.mk

Zoran Markov – Professor at Department of Hydraulic Turbines, Faculty of Mechanical Engineering Skopje, zoran.markovi@mf.edu.mk