

# Zbornik radova Proceedings

**8. Međunarodna konferencija  
o obnovljivim izvorima električne energije**  
Beograd, 16. oktobar 2020

**8<sup>th</sup> International Conference  
on Renewable Electrical Power Sources**  
Belgrade, October 16, 2020



# ZBORNİK RADOVA Proceedings

---

**pisanih za 8. Međunarodnu konferenciju o  
obnovljivim izvorima električne energije**

**8<sup>th</sup> International Conference on Renewable  
Electrical Power Sources**

CIP - Katalogizacija u publikaciji - Narodna biblioteka Srbije, Beograd

502.171:620.9(082)(0.034.2)

MEĐUNARODNA konferencija o obnovljivim izvorima električne energije (8 ; 2020 ; Beograd)

Zbornik radova [Elektronski izvor] / 8. Međunarodna konferencija o obnovljivim izvorima električne energije, Beograd, 16. oktobar 2020 ; [urednik Zoran Stević] = Proceedings / 8th International Conference on Renewable Electrical Power Sources, Belgrade, October 16, 2020 ; [editor Zoran Stević]. - Beograd : Savez mašinskih i elektrotehničkih inženjera i tehničara Srbije - SMEITS, 2020 (Beograd : Paragon). - 1 elektronski optički disk (CD-ROM) ; 12 cm

Sistemska zahteva: Nisu navedeni. - Nasl. sa naslovne strane dokumenta. - Tiraž 150. - Abstrakti. - Bibliografija uz svaki rad.

ISBN 978-86-85535-06-2

a) Энергетски извори - Одрживи развој - Зборници

COBISS.SR-ID 25077513



**ZBORNIK RADOVA  
pisanih za 8. Međunarodnu konferenciju o  
obnovljivim izvorima  
električne energije**

Hotel „Zepter“, Beograd  
16. oktobar 2020.

**PROCEEDINGS  
8<sup>th</sup> International Conference  
on Renewable Electrical  
Power Sources**

Hotel „Zepter“, Belgrade  
October 16, 2020

**Izdavač**

Savez mašinskih i  
elektrotehničkih inženjera  
i tehničara Srbije (SMEITS)  
Društvo za obnovljive izvore  
električne energije  
Kneza Miloša 7a/II,  
11000 Beograd

**Publisher**

Union of Mechanical and  
Electrotechnical Engineers and Technicians of  
Serbia (SMEITS)  
Society for Renewable Electrical  
Power Sources  
Kneza Miloša str. 7a/II,  
11000 Beograd

**Predsednik Društva za  
obnovljive izvore  
električne energije  
pri SMEITS-u**

Dr Zoran Nikolić, dipl. inž.

**President to the Society  
for Renewable Electrical  
Power Sources  
within the SMEITS**

Zoran Nikolić, Ph. D.

**Urednik**

Prof. dr Zoran Stević

**Editor**

Prof Zoran Stević, Ph. D.

**Za izdavača**

Vladan Galebović

**For Publisher**

Vladan Galebović

**Tiraž**

150 primeraka

**CD umnožava**

Paragon, Beograd

**ISBN**

978-86-85535-06-2

**Organizator  
Organizer**

Savez mašinskih i elektrotehničkih  
inženjera i tehničara Srbije (SMEITS),  
**Društvo za obnovljive izvore  
električne energije**

Union of Mechanical and Electrotechnical  
Engineers and Technicians of Serbia (SMEITS),  
**Society for Renewable Electrical  
Power Sources**

Kneza Miloša 7a/II, 11000 Beograd  
Tel. +381 (0) 11 3230-041, +381 (0) 11 3031-696, tel./faks +381 (0) 11 3231-372  
office@smeits.rs • www.smeits.rs

Održavanje 8. MKOIEE finansijski je pomoglo  
Ministarstvo prosvete, nauke i tehnološkog  
razvoja Republike Srbije



**Međunarodni programski odbor**  
**International Programme Committee**

Prof. dr Slađana Alagić	Srbija
Prof. Viorel Badescu	Rumunija
Prof. dr Pellumb Berberi	Albanija
Prof. dr Miroslav Bjekić	Srbija
Prof. dr Oleksandr Bondarenko	Ukrajina
Prof. dr Alla Denysova	Bugarska
Dr Stevan Dimitrijević	Srbija
Akademik prof. dr Zoran Đurić	Srbija
Dr Aleksandar Ivančić	Španija
Prof. dr Miroljub Jevtić	Srbija
Prof. dr Branko Kovačević	Srbija
Prof. Vladimir Krstić	Kanada
Prof. Nikolay Lopatkin	Rusija
Prof. Nikolay Mihailov	Bugarska
Prof. dr Milica Naumović	Srbija
Prof. dr Stefka Nedeltcheva	Bugarska
Dr Dušan Nikolić	Australija
Dr Zoran Nikolić	Srbija
Prof. dr Elena Ponomaryova	Ukrajina
Dr Mila Pucar	Srbija
Prof. dr Nikola Rajaković	Srbija
Prof. dr Birgit Scheppat	Nemačka
Prof. dr Valerij Sytnikov	Ukrajina
Prof. dr Velimir Stefanović	Srbija
Prof. dr Zoran Stević	Serbia (predsednik)
Prof. dr Zoran Stojiljković	Srbija
Prof. dr Volodymyr Sydorets	Ukrajina
Prof. dr Nada Štrbac	Srbija
Prof. dr Dragan Tasić	Srbija
Prof. dr Michael Todorov	Bugarska
Dr Nataša Tomić	Srbija
Dr Milica Vlahović	Srbija
Dr Zhongying Wang	Kina
Dr Wanxing Wang	Kina
Dr Xuejun Wang	Kina
Prof. dr Hengzhao Yang	SAD
Dr Ruiying Zhang	Kina

**Organizacioni odbor**  
**Organizing Committee**

Mila Pucar  
Rastislav Kragić  
Zoran Nikolić (*predsednik*)  
Ilija Radovanović  
Žarko Ševaljević  
Jelena Salević  
Vladan Galebović

## FOREWORD

*Science, technology and industry accelerated development leads to improvements of human life, but also creates new risky situations. Humanity faces unprecedented risks. Global warming is an example. Although most experts in the field of climate change state that global warming is created by humans, some scientists do not agree. One of the main problems in these risky situations is – question of responsibility. The world governments should not leave all responsibility to scientists and experts. Authorities should consult experts to declare state of emergency. A strong political initiative is necessary to start dealing with serious ecological problems such as global warming or local environment pollution. Highest level political agreements achieved within the Kyoto Protocol are not enough to stop these phenomena. Clean technologies designed to provide superior performances at lower prices, with lowering losses of conventional offerings – have great chances to be the next driving force to ensure economy growth.*

*Science is the first to define problems of Earth and life survival. Science is trying to provide solutions, limited by political, social, economic and technology factors. Preservation of life on Earth is the common priority.*

*Science and technical and technology development can contribute in several fields:*

- renewable power sources;*
- efficient energy usage;*
- waste reducing;*
- harmfulness of waste mitigation;*
- recycling;*
- soil, water and air purification;*
- residual waste neutralization.*

*Important factor for political decisions making is the public opinion. Therefore, it is extremely important to raise awareness and widely educate population on necessary transition to renewable, ecologically acceptable power sources, which is one of long-term goals of this Conference.*

*For eight time, this international event is organized by the Society of Renewable Electrical Power Sources (DOIEE) within the Union of Mechanical and Electrotechnical Engineers and Technicians of Serbia (SMETS).*

*Belgrade,  
October 2020.*

## PREDGOVOR

*Ubrzani napredak nauke, tehnologije i industrije dovodi do poboljšanja kvaliteta ljudskog života, ali i do stvaranja novih rizičnih situacija. Čovečanstvo je suočeno sa rizicima kakvih u ranijoj ljudskoj istoriji nije bilo. Globalno zagrevanje je tipičan primer. Iako većina eksperata koji proučavaju klimatske promene tvrde da globalno zagrevanje postoji i da je čovek taj koji ga uzrokuje, postoje naučnici koji dovode u sumnju takve tvrdnje. Jedan od glavnih problema vezanih za nove rizične situacije jeste – pitanje odgovornosti. Vlade država u svetu ne smeju teret odgovornosti prepustiti isključivo naučnicima i ekspertima. Vlasti treba da se konsultuju sa ekspertima i da dobro procene kada treba proglasiti opasnost od rizične situacije. Potrebna je jaka politička inicijativa da bi se počeli rešavati ozbiljni ekološki problemi kao što je globalno zagrevanje, ali i lokalno zagađenje životne sredine. Politički dogovori na svetskom nivou koji su do sada postignuti u okviru Kjoto protokola, nedovoljni su za zaustavljanje ovog fenomena. Čiste tehnologije – tehnologije koje su dizajnirane da obezbeđuju superiorne performanse za nižu cenu dok istovremeno kreiraju manji gubitak od konvencionalnih ponuda – imaju velike šanse da budu sledeća motorna snaga koja će obezbediti ekonomski rast.*

*Nauka, naravno, pre svih uočava probleme opstanka planete i života na njoj. Ona takođe pokušava da ih reši i uspeva onoliko koliko je to realno moguće, imajući u vidu političke, socijalne, ekonomske i tehnološke faktore. Može se konstatovati da su praktično svi prioriteti posvećeni očuvanju života na Zemlji. Nauka i razvoj tehnike i tehnologije mogu tome doprineti u više segmenata:*

- obnovljivi izvori energije;*
- energetska efikasnost;*
- smanjenje količine otpada;*
- smanjenje štetnosti otpada;*
- reciklaža;*
- prečišćavanje zemlje, vode i vazduha;*
- neutralizacija preostalog otpada.*

*Bitan faktor za donošenje političkih odluka je i javno mnjenje. Zato je jako važno podizanje opšte svesti i što šira edukacija stanovništva o neophodnosti prelaska na obnovljive, ekološki prihvatljive izvore energije, što je jedan od dugoročnih ciljeva ove Konferencije.*

*Ovaj međunarodni skup po osmi put organizuje Društvo za obnovljive izvore električne energije (DOIEE) Saveza mašinskih i elektrotehničkih inženjera i tehničara Srbije (SMEITS).*

*U Beogradu,  
oktobra 2020.*





# SADRŽAJ / CONTENTS

## PREDGOVOR

Prof. dr Zoran STEVIĆ . . . . . 7

## 1. Novi materijali i nove tehnologije u oblasti OIE

### Plenarno predavanje – po pozivu

1. “SUPERALKALNI“ KLASTERI, PROIZVODNJA,  
POTENCIJALNA PRIMENA KAO MATERIJAL  
ZA SKLADIŠTENJE ENERGIJE  
“SUPERALKALI” CLUSTERS, PRODUCTION, POTENTIAL  
APPLICATION LIKE ENERGY STORAGE MATERIALS  
Suzana VELIČKOVIĆ, Xianglei KONG . . . . . 15

### Redovna izlaganja

2. UPOTREBA NIKLA KAO MEĐUPREVLAKE U CILJU SMANJENJA  
KONTAKTNE KOROZIJE NA ELEKTRIČNIM KONTAKTIMA AL-CU  
USE OF NICKEL AS AN INTERMEDIATE COATING TO REDUCE  
CONTACT CORROSION ON ELECTRICAL CONTACTS AL-CU  
Silvana DIMITRIJEVIĆ, Zoran STEVIĆ, Aleksandra IVANOVIĆ,  
Stevan DIMITRIJEVIĆ, Saša MARJANOVIĆ, Nikhil DHAWAN . . . . . 23
3. SINTEZA SREBRNIH ČESTICA VELIČINE MIKROMETRA  
PRIMENJIVE ZA DEBELO FILMNE KONTAKTE  
NA SOLARNIM ČELIJAMA  
SYNTHESIS OF MICRO-SIZED SILVER PARTICLES SUITABLE  
FOR THICK FILM CONTACTS ON SOLAR CELLS  
Stevan DIMITRIJEVIĆ, Silvana DIMITRIJEVIĆ,  
Michele MILICIANI, Željko KAMBEROVIĆ,  
Zara CHERKEZOVA-ZHELEVA. . . . . 29
4. SINTEZA I KARAKTERIZACIJA PREMAZA EPOKSIDNE SMOLE  
SA POBOLJŠANOM OTPORNOŠĆU NA PLAMEN UPOTREBOM  
MODIFIKOVANE TANINSKE KISELINE  
SYNTHESIS AND CHARACTERIZATION OF EPOXY RESIN COATING  
WITH IMPROVED FIRE RESISTANCE BY THE ADDITION  
OF MODIFIED TANNIC ACID  
Andreja ŽIVKOVIĆ, Nataša TOMIĆ,  
Marija VUKSANOVIĆ, Aleksandar MARINKOVIĆ . . . . . 35
5. PRIMENA KONCEPTA 3D ŠTAMPE BETONA  
U IZRADI VETROGENERATORA  
APPLYING CONCEPT OF 3D PRINTING CONCRETE  
IN WIND TOWER CONSTRUCTION  
Aleksandar SAVIĆ, Miša STEVIĆ, Sanja MARTINOVIĆ,  
Milica VLAHOVIĆ, Tatjana VOLKOV HUSOVIĆ . . . . . 43
6. TERMOVIZIJSKI MONITORING TOPLOTE HIDRATACIJE BETONA  
THERMOVISION MONITORING OF CONCRETE HEAT OF HYDRATION  
Aleksandar SAVIĆ, Zoran STEVIĆ, Sanja MARTINOVIĆ,  
Milica VLAHOVIĆ, Tatjana VOLKOV HUSOVIĆ . . . . . 47

7.	<b>UTICAJ MEHANOHEMIJSKE AKTIVACIJE KOMPONENTI NA SINTEZU KORDIJERITNE KERAMIKE ZA PRIMENU U ELEKTRONICI</b> INFLUENCE OF MECHANOCHEMICAL ACTIVATION OF COMPONENTS ON SYNTHESIS OF CORDIERITE CERAMICS FOR APPLICATION IN ELECTRONICS Nataša ĐORĐEVIĆ, Milica VLAHOVIĆ, Slavica MIHAJLOVIĆ, Sanja MARTINOVIĆ . . . . .	51
8.	<b>UTICAJ VREMENA RELAKSACIJE AKTIVIRANE SMEŠE NA SINTEZU KERAMIKE ZA NAMENU U ELEKTRONICI</b> IMPACT OF RELAXATION TIME OF ACTIVATED MIXTURE ON CERAMICS SYNTHESIS FOR ELECTRONICS PURPOSES Nataša ĐORĐEVIĆ, Milica VLAHOVIĆ, Slavica MIHAJLOVIĆ, Sanja MARTINOVIĆ . . . . .	57
<b>2. Energetski izvori i skladištenje energije</b>		
9.	<b>POTENCIJAL POLJOPRIVREDNE BIOMASE U SISTEMIMA PROIZVODNJE BIOGASA U REPUBLICI SRBIJI</b> POTENTIAL OF AGRICULTURAL BIOMASS IN BIOGAS PRODUCTION SYSTEMS IN THE REPUBLIC OF SERBIA Olivera EĆIM-ĐURIĆ, Dragan KRECULJ, Danijela ŽIVOJINOVIĆ, Miloš VORKAPIĆ . . . . .	63
10.	<b>GASIFIKACIJA OSTATAKA BIOMASE ZA POTREBE PROIZVODNJE ELEKTRIČNE ENERGIJE</b> GASIFICATION OF BIOMASS WASTES AND RESIDUES FOR ELECTRICITY PRODUCTION Marta TRNINIĆ . . . . .	71
11.	<b>POBOLJŠANJE SVOJSTAVA BETONA DODATKOM LETEĆEG PEPELA IZ TERMOELEKTRANE ZA PRIMENU U GEOTERMALNIM SISTEMIMA</b> ENHANCING PROPERTIES OF CONCRETE BY ADDITION OF FLY ASH FROM A THERMAL POWER PLANT FOR APPLICATION IN GEOTHERMAL SYSTEMS Milica VLAHOVIĆ, Aleksandar SAVIĆ, Sanja MARTINOVIĆ, Nataša ĐORĐEVIĆ, Zoran STEVIĆ, Tatjana VOLKOV HUSOVIĆ. . . . .	77
12.	<b>PRIMENA OBNOVLJIVIH IZVORA ENERGIJE U ZGRADARSTVU</b> APPLICATION OF RENEWABLE ENERGY RESOURCES IN BUILDINGS Njegoš DRAGOVIĆ, Milovan VUKOVIĆ, Igor UROŠEVIĆ . . . . .	87
13.	<b>EFIKASNA SINHRONIZACIJA DIZEL GENERATORA U USLOVIMA PROMENLJIVE FREKVENCIJE</b> IMPROVED SYNCHRONIZATION OF DIESEL GENERATORS IN VARIABLE FREQUENCY CONDITIONS USING PREDICTIVE METHOD Zoran NIKOLIĆ, Dušan NIKOLIĆ . . . . .	95
14.	<b>KORIŠĆENJE OBNOVLJIVIH IZVORA – PRETVARANJE GEOTERMALNE ENERGIJE U ELEKTRIČNU</b> UTILIZING RENEWABLE RESOURCES – CONVERTING GEOTHERMAL ENERGY TO ELECTRICITY Miljan VLAHOVIĆ, Milica VLAHOVIĆ, Zoran STEVIĆ . . . . .	101
15.	<b>OBNOVLJIVI IZVORI ENERGIJE, POTENCIJALI I PRIMENA U SVETSKIM OKVIRIMA I U SRBIJI</b> RENEWABLE ENERGY SOURCES, POTENTIALS AND APPLICATIONS WORLDWIDE AND IN SERBIA Miomir MIKIĆ, Sanja PETROVIC, Zorica SOVRLIĆ, Daniela UROŠEVIĆ . . . . .	111

16.	<b>OCENA ŽIVOTNOG CIKLUSA BIOENERGETSKIH SISTEMA</b> LIFE CYCLE ASSESSMENT OF BIOENERGY SYSTEMS Slobodan CVETKOVIĆ, Mirjana KIJEVČANIN. . . . .	119
<b>3. Energija vetra</b>		
17.	<b>VETROTURBINE SNAGE PREKO 20 MW – TEHNOLOŠKA PERSPEKTIVA</b> WIND TURBINE BEYOND 20 MW – TECHNOLOGY PERSPECTIVE Aleksandar SIMONVIĆ, Aleksandar KOVAČEVIĆ, Toni IVANOV, Miloš VORKAPIĆ . . . . .	123
18.	<b>NUMERIČKA PROCENA AERODINAMIČKIH PERFORMANSI ROTORA VETROTURBINE SA VERTIKALNOM OSOM OBR TANJA I KONCENTRATOROM</b> NUMERICAL EVALUATION OF AERODYNAMIC PERFORMANCES OF VERTICAL-AXIS WIND TURBINE ROTOR WITH FLOW CONCENTRATOR Jelena SVORCAN, Ognjen PEKOVIĆ, TONI IVANOV, Miloš VORKAPIĆ . . . . .	135
19.	<b>UPRAVLJANJE PRETVARAČIMA U VETROTURBINAMA</b> CONTROL OF CONVERTERS IN WIND TURBINES Stevan JOKIĆ, Zoran STEVIĆ . . . . .	143
<b>4. Solarna energija</b>		
20.	<b>NAPREDNI SOFTVERSKI SISTEM ZA MONITORING SOLARNOG NAPA JANJA</b> ADVANCED SOFTWARE SYSTEM FOR MONITORING OF SOLAR PANELS Vuk JOVANOVIĆ, Ilija RADOVANOVIĆ, Zoran STEVIĆ. . . . .	155
21.	<b>ANALIZA I POREĐENJE RAZLIČITIH METODA MPPT KOD PV SISTEMA NAPA JANJA</b> ANALYSIS AND COMPARISON OF DIFFERENT MPPT METHODS IN PV POWER SYSTEMS Zoran STEVIĆ, Miša STEVIĆ, Ilija RADOVANOVIĆ . . . . .	159
22.	<b>SOLARNA ENERGIJA U SRBIJI</b> SOLAR ENERGY IN SERBIA 163 Sanja PETROVIĆ, Mimir MIKIĆ, Daniela UROŠEVIĆ . . . . .	163
23.	<b>MOGUĆNOSTI IMPLEMENTACIJE FOTONAPONSKIH SOLARNIH PANELA U PODRUČJIMA NAMENJENIM VIŠEPORODIČNOM STANOVANJU</b> POSSIBILITIES OF IMPLEMENTATION OF PHOTOVOLTAIC SOLAR PANELS IN MULTI-FAMILY HOUSING AREAS Borjan BRANKOV, Ana STANOJEVIĆ, Mila PUCAR, Marina NENKOVIĆ-RIZNIC . . . . .	167
24.	<b>PRIMENA SOLARNE ENERGIJE U FUNKCIJI ODRŽIVOG RAZVOJA U JP EPS, OGRANAK RB „KOLUBARA“ - ORG. CEL. PRERADA</b> APPLICATION OF SOLAR ENERGY IN THE FUNCTION OF SUSTAINABLE DEVELOPMENT IN PC EPS, BRANCH OF RB „KOLUBARA“ - ORG. CEL. PROCESSING Momčilo MOMČILOVIĆ, Milisav TOMIĆ. . . . .	177

## 5. Energetska efikasnost

25. **ENERGETSKA EFIKASNOST U SEKTORU JAVNIH ZGRADA NA TERITORIJI GRADA KRAGUJEVCA – STUDIJA SLUČAJA OŠ „MILUTIN I DRAGINJA TODOROVIĆ“**  
ENERGY EFFICIENCY IN THE PUBLIC BUILDINGS SECTOR IN THE TERRITORY OF THE CITY OF KRAGUJEVAC – CASE STUDY OF “MILUTIN AND DRAGINJA TODOROVIĆ” ELEMENTARY SCHOOL  
Ana RADOJEVIĆ, Aleksandar NEŠOVIĆ,  
Jasmina SKERLIĆ, Dušan GORDIĆ, Danijela NIKOLIĆ . . . . . 189
26. **SIMULACIJA INVERTORA ZA INDUKCIONO GREJANJE**  
SIMULATION OF INVERTERS FOR INDUCTION HEATING  
Biljana BAKOVIĆ, Zoran STEVIĆ. . . . . 199
27. **PRIMENA SUPERKONDENZATORA U ELEKTRIČNIM VOZILIMA**  
APPLICATION OF SUPERCAPACITORS IN ELECTRIC VEHICLES  
Zoran STEVIĆ, Ilija RADOVANOVIĆ, Miša STEVIĆ . . . . . 207
28. **ENERGETSKI EFIKASAN SISTEM ZA STERILIZACIJU DRVETA**  
ENERGY EFFICIENT SISTEM FOR WOOD STERILIZATION  
Miloš MARJANOVIĆ, Miša STEVIĆ, Miloš MILEŠEVIĆ,  
Žarko ŠEVALJEVIĆ, Sanja PETRONIĆ, Marta TRNINIĆ, Zoran STEVIĆ. . . . . 211

## 6. Aplikacije i usluge

29. **KOJE VEŠTINE SU POTREBNE U PROIZVODNJI LITIJUM-JONSKIH BATERIJA ZA ELEKTRIČNA VOZILA**  
WHAT SKILLS ARE NEEDED IN PRODUCTION OF LITHIUM-ION BATTERIES FOR ELECTRICAL VEHICLES  
Zoran KARASTOJKOVIĆ . . . . . 217
30. **PRIMENA LASERA U AUTOMOBILSKOJ INDUSTRIJI**  
APPLICATION OF LASERS IN AUTOMOTIVE INDUSTRY  
Milesa SREĆKOVIĆ, Nenad IVANOVIĆ, Stanko OSTOJIĆ,  
Aleksander KOVAČEVIĆ, Nada RATKOVIĆ KOVAČEVIĆ,  
Zoran KARASTOJKOVIĆ, Sanja JEVTIĆ . . . . . 223
31. **RASTVARANJE KATODNOG MATERIJALA IZ LIB U SUMPORNOJ KISELINI U PRISUSTVU AZOTA**  
DISSOLUTION OF LIBS CATHODE MATERIAL IN SULFURIC ACID IN THE PRESENCE OF NITROGEN  
Dragana V. MEDIĆ, Snežana M. MILIĆ, Slađana Č. ALAGIĆ,  
Zoran M. STEVIĆ, Boban R. SPALOVIĆ, Maja M. NUJKIĆ, Ivan N. ĐORĐEVIĆ. . . . . 241
32. **INTEGRACIJA DISTRIBUIRANIH PV SISTEMA U PAMETNIM SREDINAMA KORISTECI FOG COMPUTING ARHITEKTURU**  
INTEGRATION OF DISTRIBUTED PHOTOVOLTAIC SYSTEMS IN THE SMART ENVIRONMENT THROUGH FOG COMPUTING ARCHITECTURE 247  
Ilija RADOVANOVIĆ, Ivan POPOVIĆ. . . . . 247
33. **PRIMENA METODOLOGIJE PAMETNIH MREŽA U DISTRIBUCIJI ELEKTRIČNE ENERGIJE**  
SMART GRID TECHNOLOGY IN POWER DISTRIBUTION SYSTEMS  
Ivan POPOVIĆ. . . . . 251
34. **MOGUĆNOSTI PRIMENE IIOT PLATFORME U ELEKTROENERGETSKIM SISTEMIMA**  
POSSIBILITIES OF IIOT APPLICATION PLATFORMS IN THE ELECTRICAL POWER SYSTEMS 255  
Vojkan NIKOLIĆ, Zoran STEVIĆ, Stefana JANIĆIJEVIĆ, Dragan KRECULJ . . . . . 255

35.	<b>ISTRAŽIVANJE UTICAJA RELATIVNE VLAŽNOSTI I TEMPERATURE NA IOT REŠENJE ZASNOVANO NA JEFTINIM SENZORIMA ZA PRAĆENJE KVALITETA VAZDUHA</b> INVESTIGATION OF THE INFLUENCE OF RELATIVE HUMIDITY AND TEMPERATURE ON THE IOT SOLUTION WITH LOW COST AIR QUALITY MONITORING SENSORS Ivan VAJS, Dejan DRAJIĆ, Ilija RADOVANOVIĆ. . . . .	261
36.	<b>RAČUNARSKO UPRAVLJANJE ENERGETSKI EFIKASNIM SISTEMOM ZA STERILIZACIJU DRVETA</b> COMPUTER CONTROL OF ENERGY EFFICIENT WOOD STERILIZATION SYSTEM Miša STEVIĆ, Miloš MARJANOVIĆ, Ilija RADOVANOVIĆ, Zoran STEVIĆ. . . . .	267
37.	<b>VAŽNOST PRIMENE ANALIZE RIZIKA KOD OPREME POD PRITISKOM KOJA SE ISPITUJE PO POSEBNOM PROGRAMU</b> IMPORTANCE OF APPLYING RISK ANALYSIS TO PRESSURE EQUIPMENT TESTED BY A SPECIAL PROGRAM Sanja PETRONIĆ, Marko JARIĆ, Katarina ČOLIĆ, Suzana POLIĆ, Dimitrije MALJEVIĆ. . . . .	271
38.	<b>AUTOMATIZACIJA PROCESA PROIZVODNJE BAKARNE ŽICE METODOM LIVENJA U VIS – PODSISTEM ZA INDUKCIONO ZAGREVANJE</b> AUTOMATION OF A COPPER WIRE MANUFACTURING PROCESS USING UP-CASTING METHOD – SUBSYSTEM FOR INDUCTION HEATING Nada RATKOVIĆ KOVAČEVIĆ, Misa STEVIĆ, Milos MILEŠEVIĆ, Srđan MAKSIMOVIĆ, Đorđe DIHOVIČNI, Zoran STEVIĆ. . . . .	279
39.	<b>POVEĆANJE TOLERANCIJE GREŠKE ADC AD7799</b> INCREASING FAULT TOLERANCE OF ADC AD7799 Artem BASKO, Elena PONOMARYOVA. . . . .	287
40.	<b>MOGUĆNOST KORIŠĆENJA KOŠTICA VIŠNJE KAO BIOGORIVA ZA DOBIJANJE TOPLOTNE ENERGIJE</b> POSSIBILITY OF USING SOUR CHERRY PITS AS BIOFUEL FOR OBTAINING THERMAL ENERGY Milorad PETROVIĆ, Milan JOVANOVIĆ, Zoran ŠTIRBANOVIĆ, Jovica SOKOLOVIĆ, Vojka GARDIĆ. . . . .	295

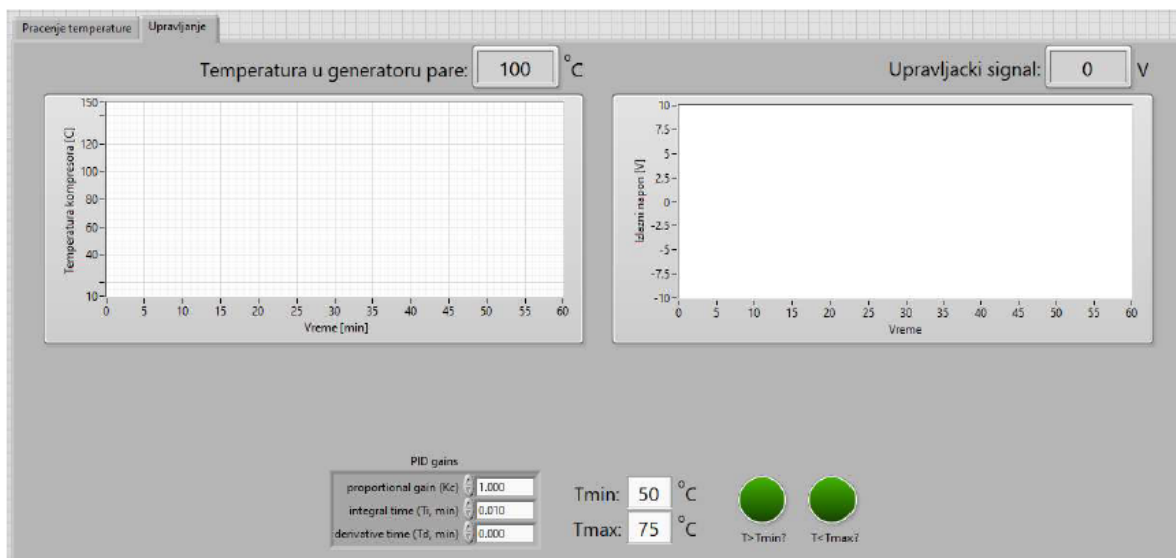


Figure 6. Front panel (setting controller parameters and monitoring output voltage)

### 3 Results

Based on the presented construction documentation, a system for wood sterilization was realized in DOO MS Kablovi in Paraćin. The system is based on an existing plant where the ON / OFF controller has been replaced by a PID controller. The new solution also brings a higher degree of protection against accidents. Significant energy savings are also achieved by the optimization algorithm for defining the set temperature of the steam generator based on the temperatures of the zones in the chamber. Computer measurement and control was performed in a LabVIEW environment, with its own application software solution (1).

### 4 Acknowledgement

The authors gratefully acknowledge financial support from the Ministry of Education and Science, Government of the Republic of Serbia.

### 5 References

- [1] **Marjanović M.**, Optimization of electrical installations in the technological process of wood thermal treatment in small dryers, Master Thesis, School of Electrical and Computer Engineering of Applied Studies, Belgrade, 2020
- [2] **Naleg, T., Kosik, S. and Fuhlborn, D.** What you need to know about SCR power controllers - Functions, features and efficiencies. <https://www.advancedenergy.com/globalassets/resources-root/white-papers/what-you-need-to-know-about-scr-power-controllers.pdf>.
- [3] \*\*\* The many benefits of SCR power control. IEEE Globaspec Media Solutions, Advanced Energy Industries, Inc., Septembar 2017.
- [4] **Isailović, M.** Temperature control using a three-phase thyristor phase controller, Thesis. Belgrade: School of Electrical Engineering, 2019.
- [5] **Hurem, Nedim**, Drying and thermal wood processing from the phitosanitary requirements aspect. Visoko, Bosnia and Herzegovina : s.n., 2019.
- [6] **Park, R., M., et al.**, Manual on the use of thermocouples in temperature measurement, 4th edition,. s.l. : ASTM Committe E20 on temperature measurement, 1993.
- [7] \*\*\* USER GUIDE: N1 USB-6001/6002/6003 Low-Cost DAQ USB device. <http://www.ni.com/pdf/manuals/374259a.pdf>. [Online]
- [8] \*\*\* Accurate calculation of PT100/PT1000 temperature from resistance.
- [9] \*\*\* <https://techoverflow.net/2016/01/02/accurate-calculation-of-pt100pt1000-temperature-from-resistance/>. [Online]

# VAŽNOST PRIMENE ANALIZE RIZIKA KOD OPREME POD PRITISKOM KOJA SE ISPITUJE PO POSEBNOM PROGRAMU

## IMPORTANCE OF APPLYING RISK ANALYSIS TO PRESSURE EQUIPMENT TESTED BY A SPECIAL PROGRAM

Sanja PETRONIĆ\*<sup>1</sup>, Marko JARIĆ<sup>1</sup>, Katarina ČOLIĆ<sup>1</sup>,  
Suzana POLIĆ<sup>2</sup>, Dimitrije MALJEVIĆ<sup>3</sup>

<sup>1</sup> Innovation Centre of the Faculty of Mechanical Engineering in Belgrade, Belgrade, Serbia

<sup>2</sup> Central Institute for Conservation, Belgrade, Serbia

<sup>3</sup> Faculty of Mechanical Engineering in Belgrade, University of Belgrade, Belgrade, Serbia

*Oprema pod pritiskom se prema PED 2014/68 i Pravilniku o tehničkim zahtevima za projektovanje, izradu i ocenjivanje usaglašenosti opreme pod pritiskom deli na opremu visokog i niskog nivoa opasnost, u zavisnosti od vrste opreme, stanja i grupe fluida i proizvoda zapremine i pritiska, odnosno akumulirane energije. Ova oprema se ispituje prema Pravilniku o pregledu opreme pod pritiskom tokom veka upotrebe. Međutim, postoji određeni broj opreme pod pritiskom koji ne može da se ispituje po redovnom programu, najčešće zbog svoje konstrukcije, ili radnog fluida. Ova oprema se ispituje po posebnom programu koji se pravi za svaku opremu posebno. U sklopu ovog programa potrebno je uraditi i analizu rizika. U ovom radu će biti pojašnjena važnost primene analize rizika i biće prikazana njena primena na određene sklopove opreme.*

**Ključne reči:** *oprema pod pritiskom, PED, analiza rizika*

*According to PED 2014/68 and the Regulation on technical requirements for design, manufacture and conformity assessment of pressure equipment, pressure equipment is divided into high- and low-level risk level equipment, depending on the type of equipment, condition and group of fluids and products of volume and pressure, i.e. accumulated energy. This equipment is tested according to the Regulation on the inspection of pressure equipment during its service life. However, there are a number of pressure equipment that cannot be tested according to a regular program, most often due to their construction, or working fluid. This equipment is tested according to a special program that is made for each equipment particular. As part of this program, it is necessary to do a risk analysis. This paper will explain the importance of applying risk analysis and will show its application to certain sets of equipment.*

**Key words:** *pressure equipment, PED, risk analysis*

### 1 Introduction

The Ordinance on technical requirements for the design, manufacture and conformity assessment of pressure equipment (1) and PED 2014/68 (2) define the conditions and obligations under which the pressure equipment is designed, manufactured and assessed, while the Ordinance on inspections of pressure equipment during life time (3) defines requirements for the safety of pressure equipment during the service life, regular and extraordinary inspections at the place of use, procedures and deadlines for inspection and testing of pressure equipment in use and the requirements to be met by the inspection bodies in order to be designated for the classification of pressure equipment and/or inspections and tests of pressure equipment, then the obligations of the user and the inspection body on inspections of pressure equipment in operation. Ordinance (3) provides for a pre-commissioning inspection, a first inspection, a regular periodic inspection and an extraordinary inspection. There are three types of regular periodic inspection: external, internal and pressure testing. In special cases, the internal examination may be replaced by an equivalent method, as well as a pressure test. However,

---

\* Corresponding author, email: sanjapetronic@yahoo.com

depending on the technical construction and / or operating conditions, there are exceptions in which the equipment needs to be tested according to a special program.

Croatian Ordinance (4) contains an appendix which lists the pressure equipment that requires treatment according to a special program. Our Ordinance (3) maintained that the Special Periodic Inspection Program is defined in the technical documentation of the pressure equipment manufacturer. This documentation contains the scope and deadlines of the examination. However, there are exceptions when the manufacturer does not provide a special program, and the equipment is subject to a special inspection program because due to the specific working conditions and technical complexity cannot be inspected according to the regular program of periodic inspections. The practice solves these problems, with the approval of Ministry of mining and energy Republic of Serbia, in a way that the user makes a special program, and the body for inspection and testing of pressure equipment approves and certifies it.

The ordinance does not define in detail what a special program for periodic inspection of pressure equipment should contain. This paper will present the role of risk analysis in compiling a special program of periodic inspections of pressure equipment, will provide an overview of standards related to risk analysis, discussed examples of pressure equipment that can not be tested by regular periodic program and analyzed and discussed example of membrane battery for which a special program was made.

## **2 Risk analysis and pressure equipment tested according to a special program**

Risk analysis is the process of assessing the probability that negative events will occur within a system, and in our case a pressure vessel. The purpose of risk analysis and assessment is to make and implement measures and decisions in order to treat certain risks and eliminate them, based on the information and evidence obtained.

Risk-based inspection (RBI) is a methodology and procedure of analysis which, unlike condition-based inspection, requires a qualitative or quantitative assessment of the probability of failure (PoF) and the consequences of failure (CoF) associated with each item of equipment, assemblies or pipelines included in a particular process unit. Properly implemented RBI program allocates individual pieces of equipment according to their risks and gives priority to inspection based on this categorization.

The ISO 31000 (Risk management - Guidelines) standard (5) defines risk management and its assessment methodology. This standard has performed a number of applied risk-based concepts, such as Quantitative Risk Assessment (QRA), Risk-Based Control (RBI), Risk-Based Control and Maintenance (RBMI), Reliability-Based Maintenance (RCM), Risk-based age management (RBLM), or simply, Risk-based management (RBM).

Standard ISO 31010 Risk management - Risk assessment techniques defines risk management, and one of the important phases is risk analysis. Cause analysis identifies risks and causes, as well as their relationship, i.e. the impact of causes on risk, assesses the probability and consequences of risk realization, proposes measures for their elimination, defines parameters for monitoring and more. The ISO 31010 standard (6) is an auxiliary standard for ISO 31000 and provides guidance on the selection and application of systematic risk assessment techniques. A risk assessment conducted in accordance with this standard contributes to other risk management activities.

Other international engineering standards dealing with this issue are: API 571: Dam-age Mechanisms Affecting Fixed Equipment in the Refining Industry (7), API 580: Risk-Based Inspection - Recommended Practice (8), API 581: Risk Based Inspection Methodology - Recommended Practice (9) and ASME PCC-3: Inspection Planning Using Risk-Based Methods (10).

Risk-based inspection (RBI) is a method in which assets are identified for inspection based on their associated risks, as opposed to a predetermined time interval. In other words, it is a planning and prioritization tool, predominantly used in the oil and gas industry, that helps identify high-priority items (i.e., high-risk ones) relative to low-priority items (i.e., high-priority items). Those with low risk). This approach allows users / property owners to increase the efficiency of their inspection



resources by concentrating them on those assets that pose the greatest risk and do not spend resources on assets that have essentially no impact.

In a risk-based inspection, the risk is calculated as a result of the probability of failure and the consequences associated with the failure.

$$\text{Risk} = \text{probability of failure} \times \text{consequences of failure}$$

Risk is usually considered a better measure of priority than the probability of failure or the consequences of failure individually, because it describes the actual damage or loss more. For example, if you have to determine the advantage of two assets where one asset has a high probability of failure but a low consequence of failure and the other asset has a low probability of failure but a high consequence of failure, the analysis will give completely opposite results if you consider only one or the other factor. The use of risk eliminates this ambiguity. The probability of failure (POF) is determined using the applicable damage factors (mechanisms), the frequency of generic failures and management system factors (10):

$$\text{POF}(t) = 1 - e^{-\text{gff} \times \text{FMS} \times \text{Df}(t)}$$

where: gff is the generic failure frequency, FMS is the control system factor and Df (t) is the overall failure factor.

The frequency of generic failures is based on industry averages of equipment failures. The management system factor is a measure of how well the plant's management and workforce are trained to handle the plant's day-to-day activities and any emergencies that may arise due to an accident. Total damage factor is a combination of different damage factors that are applicable to a particular piece of equipment being analyzed. The consequence of a failure is calculated as a combined value of the consequences of damage to damaged equipment, damage to surrounding equipment, loss of production, costs due to injury per person and damage to the environment. The consequence of a failure may include both a financial consequence (FC) and an area safety (CA) consequence (10).

Some of the pressure equipment that requires a special program of periodic inspection due to the specifics of construction or operating conditions are: pressure equipment in electrical switches and switchgear, fire protection devices, pressure equipment operating in a closed circuit, silencers, equipment under pressure intended for fire extinguishing, pressure equipment with outer shell or wall, pressure equipment for gases and gas mixtures operating at temperatures below -10°C and others.

### 3 Special program for periodic inspections of the oil / nitrogen membrane pressure accumulator

#### 3.1 Technical characteristics of the membrane pressure accumulator

Figure 1 shows a membrane oil / nitrogen pressure accumulator, manufactured by HYDAC Technology GmbH, D-66280 Sulzbach / Saar, Germany. The technical characteristics of this vessel are listed in Table 1.

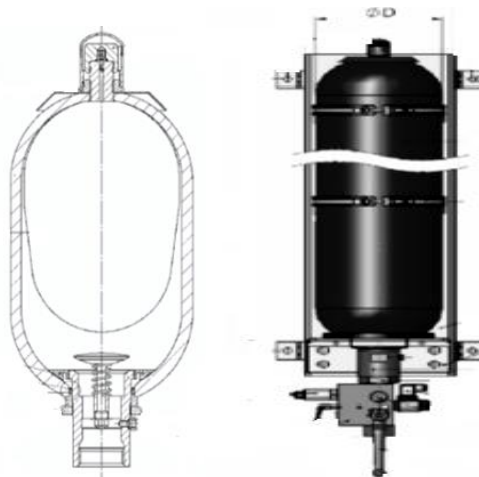


Figure 1. Membrane pressure accumulator

Table 1. Operating characteristics of a membrane pressure accumulator

Operating parameters		Unit	Value
Max allowed working pressure	PS	[bar]	330
Test pressure	PT	[bar]	472
Volume	V	[l]	10
Max allowed working temperature	TS	[°C]	100
Working fluid		-	Oil/nitrogen
Category of the pressure vessel			IV

The category of a membrane pressure accumulator is determined according to diagram 2 in (3) and belongs to the equipment of high level of danger: IV category. According to Annex III - Deadlines for regular periodic inspections, Ordinance on inspection of pressure equipment during the service life (3), the membrane accumulator should be tested according to the following dynamics: for 2 years external inspection, for 5 years internal inspection and for 10 years pressure test.

The problem that arises is the complexity of the construction in which there are no conditions to do an internal inspection or pressure test. Internal inspection can be replaced by ultrasonic measurement of wall thickness, while pressure testing by an equivalent non-destructive testing method. Considering that the accumulator is made of a seamless pipe and that there are no welded joints, it is reduced that the pressure test should be replaced by ultrasonic measurement of the wall thickness, ie two tests should be replaced by the same method. For these reasons, a special testing program is needed to conduct a risk analysis.

### 3.2 Risk analysis of the membrane pressure accumulator

Risk assessment can be quantitative, which requires a complicated procedure based on a large number of input data, or qualitative, which is reduced to assessing the degree of risk of individual components and their positioning in the risk matrix. Although the results are not as accurate as in the quantitative analysis, this approach is fully justified for pressure equipment where the operating conditions are such that there is virtually no risk of corrosion (stored medium is nitrogen / oil) and brittle fracture (negligible risk of pressure overload). In addition, in the case of the analyzed equipment under pressure for regulating the turbine plant, there are no mechanisms to reduce the wall thickness, especially if we keep in mind that the equipment is seamless, i.e. there are no welded joints, so the probability of failure is practically zero which is confirmed by history of such plants. Accordingly, the position in the risk matrix depends only on the estimated consequence, which in the worst case would be field B1, Table 2, i.e. (very) low risk.

Table 2 shows Numerical Values Associated with POF and Area-Based COF Categories taken from API 581 (9). Consequence area for this accumulator is 25m<sup>2</sup> and damage factor is 1. Based on these data and according to Table 2 the membrane pressure accumulator belongs to B1 category, i.e. low risk.

Table 2. Numerical Values Associated with POF and Area-Based COF Categories (9)

Category	Probability Category		Consequence Category	
	Probability Range	Damage Factor	Range Category	Range (m <sup>2</sup> )
1	$P_f(t) \leq 3.06E-5$	$D_f \leq 1$	A	$CA \leq 9.29$
2	$3.06E-5 < P_f(t) \leq 3.06E-4$	$1 < D_f \leq 10$	B	$9.29 < CA \leq 92.9$
3	$3.06E-4 < P_f(t) \leq 3.06E-3$	$10 < D_f \leq 100$	C	$92.9 < CA \leq 929$
4	$3.06E-3 < P_f(t) \leq 3.06E-2$	$100 < D_f \leq 1000$	D	$929 < CA \leq 9290$
5	$P_f(t) > 3.06E-2$	$D_f > 1000$	E	$CA > 9290$

Figure 2 presents Iso-Risk Plot for Consequence Area taken from API 581 (9). The values in this iso-risk plot are given in ft<sup>2</sup> and CA for this case is 269 ft<sup>2</sup>, damage factor is 1, and the accumulator is in field B1, marked with the “X”.

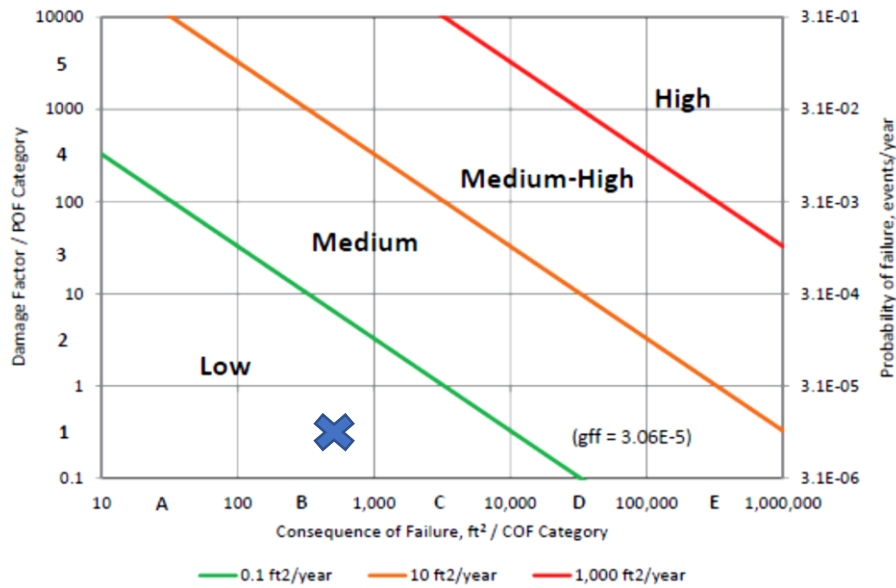


Figure 2. Iso-Risk Plot for Consequence Area (9)

Table 3 shows Numerical Values Associated with POF and Financial-Based COF Categories taken from API 581 (9). Financial risk for this accumulator is below 10000\$ and damage factor is 1. Based on these data and according to Table 3 the membrane pressure accumulator belongs to A1 category, i.e. very low risk.

Table 3. Numerical Values Associated with POF and Financial-Based COF Categories (9)

Category	Probability Category		Consequence Category	
	Probability Range	Damage Factor	Range Category	Range ( )
1	$P_f(t) \leq 3.06E-5$	$D_f \leq 1$	A	$FC \leq 10000$
2	$3.06E-5 < P_f(t) \leq 3.06E-4$	$1 < D_f \leq 10$	B	$10000 < FC \leq 100000$
3	$3.06E-4 < P_f(t) \leq 3.06E-3$	$10 < D_f \leq 100$	C	$100000 < FC \leq 1000000$
4	$3.06E-3 < P_f(t) \leq 3.06E-2$	$100 < D_f \leq 1000$	D	$1000000 < FC \leq 10000000$
5	$P_f(t) > 3.06E-2$	$D_f > 1000$	E	$FC > 10000000$

Figure 3 presents Iso-Risk Plot for Financial Consequence taken from API 581 (9). The values in this iso-risk plot are given in \$ and FC for this case is 1000\$ and damage factor is 1, and the accumulator is in field A1, marked with the “X”.

The risk matrix is presented in Figure 4, and fields related to the membrane pressure accumulator are marked with “X”.

This assessment is also influenced by the fact that the risk of accident is lower than the risk of testing, i.e. discharge of this type of pressure equipment, even when controlled, could cause severe consequences.

For this level of risk, the prescribed program for measuring wall thickness every 5 years is conservative because it prevents all possible adverse events and ensures safe operation of the plant.

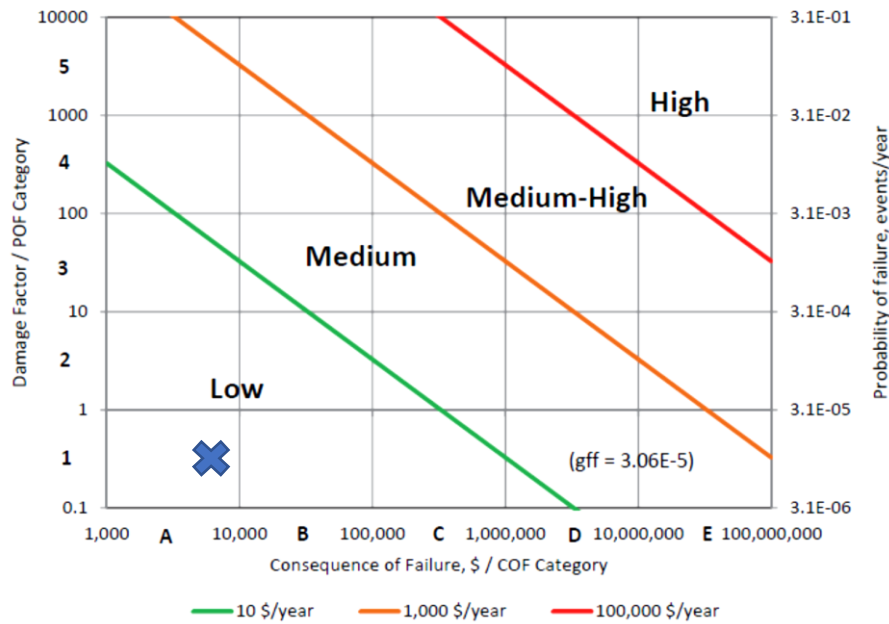


Figure 3. Iso-Risk Plot for Financial Consequence (9)

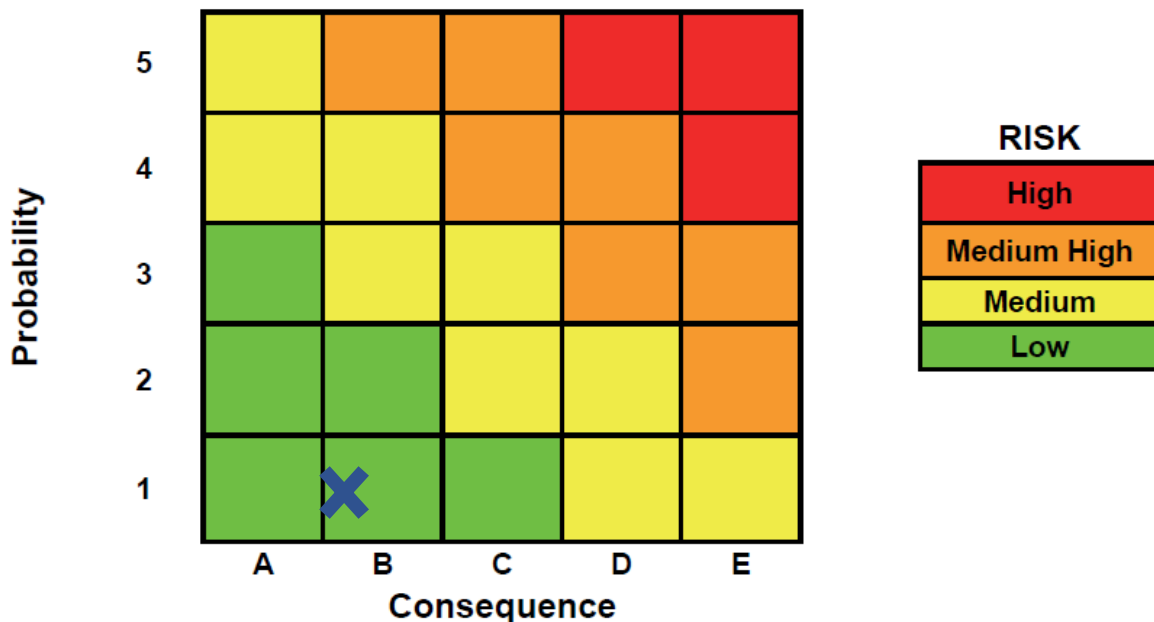


Figure 4. Risk matrix

### 3.3 Determining the periodicity of subsequent inspections according to the Special Program

External inspection (every 2 years) according to the inspection period assigned in the Ordinance on inspection of pressure equipment during the service life (3).

Visually inspect every two years to check:

- whether there are irregularities and deviations in relation to the technical documentation,
- general condition of membrane accumulator, condition of the supporting structure, connections, accompanying pipelines and safety devices,
- condition of the working environment and plant in which the equipment is located,
- anti-corrosion protection of external surfaces of equipment,
- whether the equipment is used in accordance with the purpose.

Ultrasound wall thickness measurement (every 5th year)

Measurement of wall thickness by ultrasound of cylindrical shells of membrane pressure accumulator should be performed every five years according to the schema given in Figure 5.

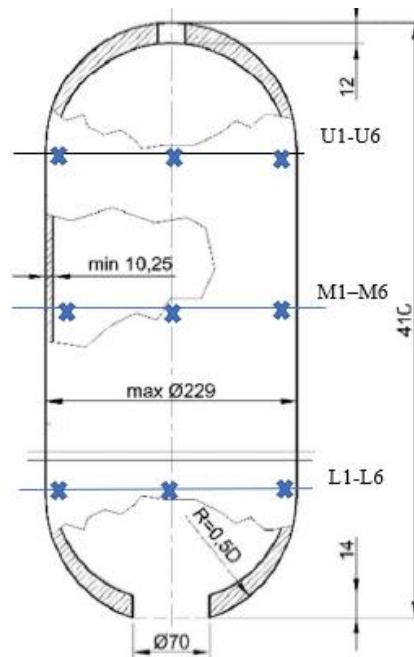


Figure 5. Measuring points U1-U6, M1-M6 and L1-L6 on the membrane accumulator

The minimum wall thickness of the seamless cylindrical shells of membrane pressure accumulators according to the strength calculation is 10.25 mm.

Table 3 gives the results of ultrasound measuring the wall thickness at the measuring points shown in Figure 5.

Table 3. Results of ultrasound measurement of the wall thickness

Point of measurement / Line of measurement	1	2	3	4	5	6
U	11, 3	11, 2	11, 3	11, 3	11, 1	11, 1
M	11, 1	11, 4	11, 2	11, 1	11, 1	11, 4
L	11, 3	11, 3	11, 1	11, 2	11, 2	11, 2

The minimum measured wall thickness of seamless cylindrical shells of membrane pressure accumulators must not be less than the minimum wall thickness as required by the manufacturer and the required wall thickness given in the strength calculation. The derived wall thickness of the lower and upper hemispherical bottom is from 10.25 to 14 mm. The membrane pressure accumulator has no welded joints. Due to the operating conditions, the working medium and the large difference between the required and derived wall thickness, it is not necessary to measure the wall thickness of the lower and upper hemispherical bottoms of membrane accumulators.

#### 4 Conclusion

This paper presents and explains the importance of risk analysis in the preparation of inspections and tests of pressure equipment according to a special program.

The paper presents an example of risk analysis and test periodicity for membrane pressure accumulators.

It has been shown that the risk of accidents is very small and that tests can be performed for 5 years, which would save money.

The risk analysis showed that no critical high risk positions were observed, and that none of the elements of membrane accumulator tends to move to the category of higher risk in the case when the review and testing program is realized in the next review and testing dates given in this program.

## 5 Reference

- [1] \*\*\* Rulebook on technical requirements for design, manufacture and conformity assessment of pressure equipment, Official Gazette RS, 87/2011, 2011
- [2] \*\*\* DIRECTIVE 2014/68/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 15 May 2014 on the harmonisation of the laws of the Member States relating to the making available on the market of pressure equipment, Official Journal of the European Union, 2014
- [3] \*\*\* Rulebook on inspections of pressure equipment during the service life, Official Gazette of RS, 87/2011 i 75/2013
- [4] \*\*\* Ordinance on the inspection and testing of pressure equipment, Official Gazette of Croatia, 80/2013 i 14/2014
- [5] \*\*\* ISO 31000: 2018 Risk management – Guidelines, International Organization for Standardization, 2018.
- [6] \*\*\* IEC 31010: 2019, Risk management – Risk assessment techniques, International Organization for Standardization, 2019.
- [7] \*\*\* API 571: Damage Mechanisms Affecting Fixed Equipment in the Refining Industry, American Petroleum Institute, 2020.
- [8] \*\*\* API 580: Risk-Based Inspection - Recommended Practice, American Petroleum Institute, 2016.
- [9] \*\*\* API 581: Risk Based Inspection Methodology - Recommended Practice, American Petroleum Institute, 2016.
- [10] \*\*\* ASME PCC-3: Inspection Planning Using Risk-Based Methods, The American Society of Mechanical Engineering, 2017.

# AUTOMATIZACIJA PROCESA PROIZVODNJE BAKARNE ŽICE METODOM LIVENJA U VIS – PODSISTEM ZA INDUKCIONO ZAGREVANJE

## AUTOMATION OF A COPPER WIRE MANUFACTURING PROCESS USING UP-CASTING METHOD – SUBSYSTEM FOR INDUCTION HEATING

Nada RATKOVIĆ KOVAČEVIĆ<sup>\*1</sup>, Misa STEVIĆ<sup>2</sup>, Milos MILEŠEVIĆ<sup>3</sup>,  
Srđan MAKSIMOVIĆ<sup>4</sup>, Đorđe DIHOVIČNI<sup>5</sup>, Zoran STEVIĆ<sup>6</sup>

<sup>1</sup> The Academy of Applied Technical Studies Belgrade, Belgrade, Serbia

<sup>2</sup> Mikroelektronika, Belgrade, Serbia

<sup>3</sup> School of Electrical Engineering, University of Belgrade, Belgrade, Serbia

<sup>4</sup> The Academy of Applied Technical Studies Belgrade, Belgrade; Trizma, Belgrade, Serbia

<sup>5</sup> The Academy of Applied Technical Studies Belgrade, Serbia

<sup>6</sup> School of Electrical Engineering, University of Belgrade, Technical faculty in Bor,  
University of Belgrade; Central Institute of Conservation, Belgrade, Serbia

<https://doi.org/10.24094/mkoiee.020.8.1.279>

*Cilj ovde predstavljenog istraživanja je da se projektuje i implementira sistem za automatsku proizvodnju bakarne žice, metodom livenja u vis (eng. up-casting). Podsystem indukcionog zagrevanja obuhvata automatsku kontrolu temperature bakra, topljenog kao i žarenog, automatsko regulisanje snage indukcionog zagrevanja, kako bi se omogućilo pravilno grejanje bakarne žice, tako da se može dostići potrebna temperatura, i postiglo žarenje ili topljenje. Zavojnica je izrađena od bakarne cevi i njena temperatura se reguliše pomoću prisilnog proticanja ulja kroz cev. Sistem se može lako prilagoditi za automatsko žarenje čelične žice ili žice od železa, imajući u vidu električna i magnetska svojstva železa i čelika. Sistem je proizveden, testiran i stavljen u funkciju.*

**Ključne reči:** automatizacija; indukciono zagrevanje; mehatronika; žarenje

*The aim of the research presented here is to design and implement a system for automatic production of copper wire, by the method of up-casting. The subsystem for induction heating includes automatic control of the temperature of the melted as well as annealed copper, automatic regulation of the induction heating power. The induction coil was designed and made to provide proper heating of the copper wire that is produced, so that the necessary temperature can be reached and its annealing or melting obtained. The coil is made of copper tube and its temperature is regulated using forced oil flow through the tube. The system can be easily adapted to be used in automation of the process of steel wire or iron wire annealing, having in mind the electrical and magnetic properties of the steel and iron. The system was produced, tested and put to work.*

**Key words:** annealing; automation; induction heating; mechatronics

### 1 Introduction

Induction heating is the process of heating an electrically conducting object (usually a metal) by electromagnetic induction, through heat generated in the object by eddy currents [1]. Induction heating is based on conversion of electro-magnetic field energy into heat [2]. This conversion is obtained through electromagnetic induction which is performed in systems for induction heating. The systems for induction heating can be with or without magnetic core [2].

An induction heater consists of an electromagnet and an electronic oscillator that passes a high-frequency alternating current (AC) through the electromagnet [1]. The rapidly alternating magnetic field penetrates the object, generating electric currents inside the conductor, called eddy currents. These currents flowing through the material cause the metal to be heated by Joule heating, because

<sup>\*</sup> Corresponding author, email: nratkovicmf@gmail.com

## 4 Conclusion

The Republic of Serbia has great potential in agricultural biomass with 1.67 million toe, but it is not used enough. The most of electrical energy in Serbia (over 60%) is being generated by coal combustion. Coal is also often being used as a fuel for household heating, so the air in Serbia is much polluted especially in the winter season. Using renewable energy resources like biomass instead of coal can contribute to improving air quality and also preservation natural resources of coal.

Residues from fruit processing such as plum pits, peach pits, sour cherry pits, walnut shells, etc. can be used for heating instead of wood or coal. Serbia has significant resources in fruit production which could be used. Sour cherry is fourth fruit specie in Serbia, in terms of area that it is being cultivated on. Average annual production of sour cherry in Serbia is approximately 80000 tons, and 7000 tons represents residue from processing industry. Sour cherry pits have good calorific value (21,75 MJ / kg of dry matter) and their shape and size are convenient for using in wood pellet boilers. Company Šukom from Knjaževac produces wood pellet boilers Šukoplam VENT, which is distinguished with high efficiency (up to 94%), quality of materials and workmanship and the possibility of using several types of biofuels and their quality combustion.

## 5 Acknowledgment

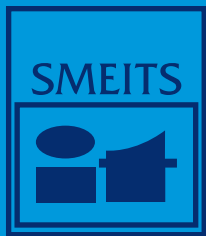
The research presented in this paper was done with the financial support of the Ministry of Education, Science and Technological Development of the Republic of Serbia, within the funding of the scientific research work at the University of Belgrade, Technical Faculty in Bor, according to the contract with registration number 451-03-68/2020-14/20013.

## 6 References

- [1] \*\*\* *Energy Sector Development Strategy of the Republic of Serbia for the period by 2025 with projections by 2030*, Republic of Serbia, Ministry of Mining and Energy, Department for strategic planning in energy sector, Belgrade, Serbia, 2016.
- [2] \*\*\* **ARCOTRASS - Consortium**, *Study on the State of Agriculture in Five Applicant Countries – Country Report: Serbia*, 2006.
- [3] **Dragović, Nj. M., M. D. Vuković, D. T. Riznić**, Potentials and prospects for implementation of renewable energy sources in Serbia, *Thermal science, Volume23*, (2019), issue 5B, pp. 2895-2907.
- [4] **Keserović, Z., N. Magazin, B. Milić, M. Dorić**, *Voćarstvo i vinogradarstvo*, Univerzitet u Novom Sadu, Poljoprivredni fakultet, Novi Sad, Srbija, 2016.
- [5] **Kovačević, V.**, *Status of Using Agricultural Biomass for Energy Purposes in Serbia*, UNDP Serbia, 2018.
- [6] \*\*\* <http://media.popispoljoprivrede.stat.rs/2014/Dokumenta/Radovi/03%20Vocarstvo%20Srbije%20%E2%80%93%20stanje%20i%20perspektive.pdf>
- [7] \*\*\* <http://media.popispoljoprivrede.stat.rs/2014/Dokumenta/Prezentacije/03%20Vocarstvo%20Srbije%20%E2%80%93%20stanje%20i%20perspektive.pdf>
- [8] **Đević, M., A. Dimitrijević, D. Blažin, S. Blažin**, Possibilities of using fruit processing residues as burning material, *Journal of Processing and Energy in Agriculture, Volume12*, (2008), issue 3, pp. 111-114.







**8. Međunarodna konferencija o obnovljivim izvorima električne energije**

Beograd, 16. oktobar 2020

**8<sup>th</sup> International Conference on Renewable Electrical Power Sources**

Belgrade, October 16, 2020