6th International Conference <EnRe>

energy & responsibility

Book of Extended Abstracts

Sebastijan SEME
Klemen SREDENŠEK
EDITORS

University of Maribor Press

University of Maribor

Faculty of Energy Technology

6th International Conference
EnRe – Energy and Responsibility

Book of Extended Abstracts

Editors

Sebastijan Seme

Klemen Sredenšek

May 2024

Title **6th International Conference EnRe - Energy & Responsibility**

Subtitle **Book of Extended Abstracts**

Editors Sebastijan Seme
(University of Maribor, Faculty of Energy Technology)

Klemen Sredenšek
(University of Maribor, Faculty of Energy Technology)

Language editing Adele Gray

Technical editors Marina Bajić
(University of Maribor, University Press)

Jan Perša
(University of Maribor, University Press)

Cover designer Jan Perša
(University of Maribor, University Press)

Cover graphics University of Maribor, Faculty of Energy Technology, 2022; flower from Pixabay.com, CC0, 2022

Graphic material Source are own unless otherwise noted.
Authors and Seme, Sredenšek (editors), 2024

Conference **6th International Conference EnRe - Energy & Responsibility**

Date and location 21st of May 2024, Velenje, Slovenia

International Scientific Commitee Sebastijan Seme (chairman), Marinko Barukčić, Amor Chowdhury, Nenad Cvetković, Goga Cvetkovski, Brigita Ferčec, Matej Fike, Adnan Glotić, Miralem Hadžiselimović, Željko Hederić, Gorazd Hren, Ankica Kovač, Samar Al Sayegh Petkovšek, Boštjan Pokorny, Zdravko Praunseis, Janez Rošer, Jurij Avsec, Natalija Špeh, Bojan Štumberger, Gorazd Štumberger, Zdravko Virag, Peter Virtič, Mykhailo Zagirnyak, Marija Živić

Local Organising Committee Sebastijan Seme, Gašper Gantar, Boštjan Kranjc, Sonja Krajnc, Jurij Avsec, Karla Sitar, Klemen Sredenšek, Mitja Tašler, Franc Žerdin

Published by **University of Maribor, University Press**
Slomškov trg 15, 2000 Maribor, Slovenia
https://press.um.si, zalozba@um.si

Issued by **University of Maribor, Faculty of Energy Technology**
Hočevarjev trg 1, 8270 Krško, Slovenia
Koroška cesta 62a, 3320 Velenje, Slovenia
https://www.fe.um.si, fe@um.si

Edition 1st **Published at** Maribor, Slovenia, May 2024

Publication type E-book **Available at** https://press.um.si/index.php/ump/catalog/book/874

CIP - Kataložni zapis o publikaciji
Univerzitetna knjižnica Maribor

621.311(082)(0.034.2)

INTERNATIONAL Conference En-Re Energy & Responsibility (6 ; 2024 ; Velenje)
6th International Conference En-Re Energy & Responsibility [Elektronski vir] : [21st of May 2024, Velenje, Slovenia] : book of extended abstracts / editors Sebastijan Seme, Klemen Sredenšek. - 1st ed. - E-knjiga. - Maribor : University of Maribor, University Press, 2024

Način dostopa (URL):
https://press.um.si/index.php/ump/catalog/book/874
ISBN 978-961-286-863-5 (PDF)
doi: 10.18690/um.fe.2.2024
COBISS.SI-ID 195465987

ISBN 978-961-286-863-5 (pdf) **DOI** https://doi.org/10.18690/um.fe.2.2024

Price Free copy **For publisher** Prof. Dr. Zdravko Kačič, Rector of University of Maribor

Attribution Seme, S., Sredenšek, K. (eds.). (2024). *6th International Conference EnRe - Energy & Responsibility: Book of Extended Abstracts.* Maribor: Unversity of Maribor, University Press. doi: 10.18690/um.fe.1.2024

Table of Contents

<EnRe>
energy & responsibility

PLENARY SESSION

6TH INTERNATIONAL CONFERENCE ENRE - ENERGY & RESPONSIBILITY
BOOK OF EXTENDED ABSTRACTS
S. Seme, K. Sredenšek (eds.)

University of Maribor Press

NECP UPDATE GOALS AND LOCAL ENERGY UPPLY

STANE MERŠE
Jozef Stefan Institute – Energy Efficiency Center, Ljubljana, Slovenia
stane.merse@ijs.si

Keywords: strategic energy planning, climate energy policy, energy union, energy efficiency, renewable energy sources, GHG mitigation, district heating and cooling, local planning.

The update of the National Energy and Climate Plan (NECP) seeks Slovenia's answers to tackling the global climate and EU's energy crisis successfully, with the aim of achieving climate neutrality by 2050. The paper will present new, more ambitious targets for all five dimensions of the Energy Union by 2030, key policies and measure, and impact assessment of the analysed scenarios. Increasing energy and resource efficiency in all sectors is the first prerequisite for a successful and cost-effective replacement of fossil fuels by renewable and other low-carbon energy sources. A just transition from coal by 2033 at the latest is Slovenia's biggest strategic challenge here, especially in terms of ensuring the security of the energy supply. The implementation of a large number of dispersed projects, as well as the efficient siting of large hydro and wind power projects, will be key to increasing the use of renewable energy sources. Successful achievement of the national targets will require a systematic transfer of these objectives to the local level, in particular, through quality support for local planning of energy infrastructure, focusing on district heating and cooling (DHC) systems. These systems are facing a major challenge of energy renovation and the transition to renewables and excess heat, which is key to achieving the required efficiency criteria, and, above all, competitiveness in district heating and cooling. The main orientations and scenarios for the development of the DHC systems will be presented, as well as estimates of the needed investments.

References

IJS-CEU et al (2024). Osnutek predloga posodobitve (2024): CELOVITI NACIONALNI ENERGETSKI IN PODNEBNI NAČRT REPUBLIKE SLOVENIJE, Ministrstvo za okolje, podnebje in energijo RS.

Vlada RS (2020). Celoviti nacionalni energetski in podnebni načrt republike Slovenije, Vlada RS, Ministrstvo za okolje, podnebje in energijo RS.

Regulation (EU) 2018/1999 on the governance of the energy union and climate action.

6TH INTERNATIONAL CONFERENCE ENRE - ENERGY & RESPONSIBILITY
BOOK OF EXTENDED ABSTRACTS
S. Seme, K. Sredenšek (eds.)

University of Maribor Press

GREEN TRANSFORMATION OF THE ŠALEŠKA VALLEY DISTRICT HEATING SYSTEM

GAŠPER ŠKARJA
University of Maribor, Faculty of Law, Maribor, Slovenia
gasper.skarja@kp-velenje.si

Keywords: district heating system, just transition, carbon-free, Action plan, green transition

The Šaleška Valley District Heating System (DOVE)

The future of the district heating system in the Šaleška Valley lies in green transformation and resource dispersion.

The planned exit from coal by 2033, according to the guidelines of theState and the EU, requires a complete transformation of this second largest district heating system in Slovenia, supplying up to 35,000 customers and over 650 industrial users. Established in 1959 as the first and leading system in the former Yugoslavia, the existing system has been a key contributor to the environmental rehabilitation of the Šaleška Valley.

In order to obtain environmental remediation, the necessity of maintaining the Šaleška Valley district heating system as a whole entity is crucial. Ensuring a stable and sustainable supply of heat is one of the essential pillars of a just transition to a carbon-free society.
Today, District heating in the Šaleška valley is dependent on one production source only: the Šoštanj Thermal Power Plant, coal. In order to reduce the use of fossil energy sources and their import dependency by phasing out coal, the Velenje Utility company is preparing a more than €130 million worth transformation of the existing system. Together with a consortium of partners and a wide range of expertise and references (ELES, Esotech,

Kolector Setup, KPV, KSSENA and Resalta), we prepared a draft Action plan for the transformation.

The transition to a new district heating system in the Šaleška Valley will result in a more economic, efficient, and coal-free system. As part of the transformation of the district system, it strives to achieve 100% of its own resources.

The green transition will be staged as follows:

- Pipeline renewal and digitalisation of the distribution network,
- Renovation of heat supply substations,
- Lowering the temperature regime and operation from the current 140/70°C at 85(110)/45°C (early summer average 112/74 °C),
- Design and build new heat production units from renewable sources in phases,
- The necessity of simultaneous energy renovation of buildings for the transition to a lower temperature regime.

The Action plan foresees the following sources of heat production: wood biomass - cogeneration of heat and electricity, a solar heat plant, water-to-water heat pumps by exploiting the potential of Lake Velenjska and waste water at the Central Wastewater Treatment Plant of the Šalek Valley, the installation of a high-voltage electrode boiler and a heat storage tank.

As a result, total savings on renewal pipelines, buildings and construction of new heat stations are estimated CO_2 emission reductions of **25.269** t and a reduction in the amount of coal by **21.150 t** per year.

The Action plan follows the objectives of green transformation, aiming for a reliable heat supply from renewable sources, reduction of greenhouse gases, a safe, stable and independent source of energy and affordable prices for electricity and heating for all residents of the Šaleška Valley, and thereby preventing or limiting energy poverty.

References

National Strategy for Coal Phase-out and Restructuring of Coal Regions (2021)
Akcijski načrt za prehod iz premoga Savinjsko-šaleške premogovne regije (Deloitte May 2021)

<EnRe>
energy & responsibility

ELECTRICAL DEVICES, MACHINES AND DRIVES

6TH INTERNATIONAL CONFERENCE ENRE - ENERGY & RESPONSIBILITY
BOOK OF EXTENDED ABSTRACTS
S. Seme, K. Sredenšek (eds.)
University of Maribor Press

PROSUMER-RICH DISTRIBUTION POWER NETWORK – PROPOWERNET

GORAN KNEŽEVIĆ, DANIJEL TOPIĆ
Josip Juraj Strossmayer University of Osijek, Faculty of Electrical Engineering, Computer Science and Information Technology, Osijek, Croatia
goran.knezevic@ferit.hr, danijel.topic@ferit.hr

Keywords: distribution network, integration, optimization, prosumer, PV systems, research group

Electricity generation from most of the renewable energy sources (RES) based power plants is generally variable and unpredictable, which causes difficulties in the electricity grid planning and operation, while this effect is magnified even more by the massive integration of such power plants. Previous passive consumers, by integration of RES based power plants in their ownership, are becoming prosumers. The development of a prosumer energy management system is a multidisciplinary process that involves multiple aspects that must be considered. The purpose of this project is to establish a research group to study the operation of a prosumer system and distribution network (DN) within four aspects of observation: i) maximizing the prosumer`s profit by participating on the electricity and ancillary services markets; ii) optimization of the DN operation with the objectives of power losses minimization and maintaining the desired loading and voltage levels in the network; iii) reducing the impact on the power quality; iv) maintaining the voltage and frequency stability of the network when large numbers of prosumers are connected to the DN. The objectives of the project include developed simulation models for analyzing the interactions of the DN and the prosumer system, as well as the developed optimization algorithms for determining the optimum drive of the prosumer devices and DN for various aspects of observation. The results of the project will contribute to the

possibility of large-scale integration of prosumers in the DN, while maintaining the frequency and voltage stability of the system and the prescribed level of power quality.

References

Mišljenović N, Žnidarec M, Knežević G, Šljivac D, Sumper A. A Review of Energy Management Systems and Organizational Structures of Prosumers. Energies. 2023; 16(7):3179. https://doi.org/10.3390/en16073179

Dubravac M, Fekete K, Topić D, Barukčić M. Voltage Optimization in PV-Rich Distribution Networks—A Review. Applied Sciences. 2022; 12(23):12426. https://doi.org/10.3390/app122312426

Šimić Z, Topić D, Crnogorac I, Knežević G. Method for Sizing of a PV System for Family Home Using Economic Indicators. Energies. 2021; 14(15):4529. https://doi.org/10.3390/en1415452

Dubravac M, Žnidarec M, Fekete K, Topić D. Multi-Stage Operation Optimization of PV-Rich Low-Voltage Distribution Networks. Applied Sciences. 2024; 14(1):50. https://doi.org/10.3390/app14010050

Rojnić M, Prenc R, Topić D, Strnad I, A new methodology for optimization of overcurrent protection relays in active distribution networks regarding thermal stress curves, International Journal of Electrical Power & Energy Systems. 2023; 152:109216. https://doi.org/10.1016/j.ijepes.2023.109216.

Mišljenović N, Šimić Z, Topić D, Knežević G, An algorithm for the optimal sizing of the PV system for prosumers based on economic indicators and the input data time step, Solar Energy. 2023; 262:111882. https://doi.org/10.1016/j.solener.2023.111882.

6TH INTERNATIONAL CONFERENCE ENRE - ENERGY & RESPONSIBILITY
BOOK OF EXTENDED ABSTRACTS
S. Seme, K. Sredenšek (eds.)
University of Maribor Press

INFRARED THERMOGRAPHY IN THE DETECTION OF WATER STRESS IN PLANTS

HRVOJE GLAVAŠ,[1] MONIKA MARKOVIĆ,[2] ANTONIJA STRILIĆ[2]

[1] Josip Juraj Strossmayer University of Osijek, Faculty of Electrical Engineering, Computer Science and Information Technology, Osijek, Croatia
hrvoje.glavas@ferit.hr
[2] Josip Juraj Strossmayer University of Osijek, Faculty of Agrobiotechnical Sciences, Osijek, Croatia
monika.markovic@fazos.hr, akojic@fazos.hr

Keywords: thermohraphy, water stress, plant, UHI, electrical energy

Plants and green islands in urban areas are one way to mitigate climate change and reduce the energy demand for air conditioning. Like humans, plants are also exposed to the urban heat island effect, which manifests itself in the fact that air temperatures in urban areas are, on average, 2-5°C higher than in rural areas. In addition, plants are exposed to water stress, which occurs when the amount of available water exceeds or falls short of the plants' water requirements. The paper presents an increase in electricity demand with a special focus on Croatia, Slovenia and countries with similar electricity consumption. The effects of the urban heat island are illustrated using a graphical comparison from recent literature. Infrared thermography, as one of the methods for detecting water stress, is explained with the physical background of long-wave radiation detection and compared with near infrared digital photography. All possible aspects are presented of radiation detection that occur during thermographic analysis. A specific overview of water stress is given, and its effects are illustrated using examples of plant height and flower size. The application of infrared thermography in the detection of water stress is illustrated using thermograms of wheat in a dry field and after irrigation. On this basis, a conclusion was drawn about the possibility of using infrared thermography in the detection of water stress.

References

Clara Camarasa, (2023)Public webinar - IEA's Energy Efficiency 2023 Report: Key findings and a chance to discuss with Lead Authors, Odyssee-Mure, 7 December 2023

Glavaš, H.; Hadzima-Nyarko, M.; Haničar Buljan, I.; Barić, T. (2019) Locating Hidden Elements in Walls of Cultural Heritage Buildings by Using Infrared Thermography. Buildings, 9, 32. https://doi.org/10.3390/buildings9020032

Government of South Australia, Department for Energy and Mining (2023) 'Demand response capability requirements for installation of all air conditioning types', Technical Regulator Guideline, Energy and Technical Regulation

Jones, Hamlyn G and Eyal Rotenberg. (2011) Energy, Radiation and Temperature Regulation in Plants., DOI: 10.1038/npg.els.0003199

Livada, Časlav, Hrvoje Glavaš, Alfonzo Baumgartner, and Dina Jukić. (2023) The Dangers of Analyzing Thermographic Radiometric Data as Images, Journal of Imaging 9, no. 7: 143. https://doi.org/10.3390/jimaging9070143

Mahendra Bhandari (2016) Use of infrared thermal imaging for estimating canopy temperature in wheat and maize, Ms Thesis, West Texas A&M University, Canyon, Texas,

Marković, M., Josipović, M., Tadić, V., Zebec, V., Josipović, M., Filipović, V. (2015): Efficiency of maize irrigation scheduling in climate variability and extreme weather events in eastern Croatia. Journal of water and climate change, 6(3): 586-595.

Massaro, E., Schifanella, R., Piccardo, M. et al. (2023) Spatially-optimized urban greening for reduction of population exposure to land surface temperature extremes. Nat Commun 14, 2903 https://doi.org/10.1038/s41467-023-38596-1

Önder, Serpil; Akay, Ahmet: The Roles of Plants on Mitigating the Urban Heat Islands' Negative Effects, International Journal of Agriculture and Economic Development, ISSN : 2331-0200

Pineda, M.; Barón, M.; Pérez-Bueno, M.-L. (2021) Thermal Imaging for Plant Stress Detection and Phenotyping. Remote Sens., 13, 68.

Schwaab, J., Meier, R., Mussetti, G. et al. (2021) The role of urban trees in reducing land surface temperatures in European cities. Nat Commun 12, 6763 https://doi.org/10.1038/s41467-021-26768-w

Sun, Y., Wang, C., Chen, H.Y.H., Honghua, R. (2020): Response of Plants to Water Stress: A Meta-Analysis. Front. Plant Sci., 11: 978.

Vaz Monteiro, Madalena & Handley, Phillip & Morison, James & Doick, Kieron. (2019). The role of urban trees and greenspaces in reducing urban air temperatures.

Wu, J.; Wang, J.; Hui, W.; Zhao, F.; Wang, P.; Su, C.; Gong, W. (2022) Physiology of Plant Responses to Water Stress and Related Genes: A Review. Forests, 13, 324.

6TH INTERNATIONAL CONFERENCE ENRE - ENERGY & RESPONSIBILITY
BOOK OF EXTENDED ABSTRACTS
S. Seme, K. Sredenšek (eds.)

University of Maribor Press

DETERMINATION OF THREE-PHASE DIODE RECTIFIER PARAMETERS FOR DISCONTINUOUS CONDUCTION MODE

ERMIN BEGANOVIĆ,[1] MENSUR KASUMOVIĆ,[1] MARINA PEJIĆ,[1]
VIKTOR MILARDIĆ,[2] AMIR TOKIĆ[1]

[1] University of Tuzla, Faculty of Electrical Engineering, Tuzla, Bosnia and Herzegovina
ermin.beganovic@fet.ba, mensur.kasumovic@fet.ba, marina.pejic@fet.ba, amir.tokic@fet.ba
[2] University of Zagreb, Faculty of Electrical Engineering and Computing, Zagreb, Croatia
viktor.milardic@fer.hr

Keywords: three-phase rectifier, harmonics, discontinuous conductive mode, parameter determination, Nelder-Mead method

Three-phase diode rectifiers (uncontrolled bridge rectifiers) with capacitive dc smoothing are used widely in low voltage and industrial apllications today (Sun et al., 2016). Areas of their application are: the input stage in low to medium variable frequency drives, dc-dc converters, telecommunications and electric vehicle chargers.

These devices generate a considerable distorsion level and harmonic content of ac input currents. For this reason, it is very important to develop the correct models of these nonlinear elements, in order to simulate network harmonics accurately. The structure of these rectifiers is usually known when developing their electrical model. However, the parameters of this model are mostly unknown. The published papers usually deal with the modelling of elements in the time domain and harmonic domain, where analytical or numerical methods are used to simulate the operation of these devices.

A relatively small number of papers deal with the determination of rectifier parameters; mostly single-phase rectifiers (Tokić et al., 2016), and, less often, three-phase rectifiers (Duenas et al., 2020).

For typical three-phase diode rectifiers there are two basic operating modes: discontinuous conductive mode (DCM) and continuous conductive mode (CCM). These two modes can appear during balanced or unbalanced source voltages. The main focus of this paper is the determination of the three phase diode rectifier parameters considering the discontinuous conductive mode. Three phase balanced source voltages will be assumed.

For the time subinterval of the continuity and discontinuity of the current, the corresponding state space equations will be derived, and, after that, will be solved by the Cayley-Hamilton theorem in the Time domain. Based on the analytical solution for input ac currents, an objective function will be formed, that minimizes the square deviation between the calculated and referent input currents. The minimization of the objective function will be performed using the Nelder-Mead method, since this method is very useful for relatively low problem dimensions and has no difficulty in finding derivatives and discontinuity functions during the optimization process. Because of eventual convergence problems, special attention will be paid to the initial condition calculations. At the end, a comparison of the assumed initial parameters of the rectifier, its exact parameters and parameters estimated by using the procedure based on the Nelder-Mead optimization method and proposed objective function will be shown.

References

Sun, Y., Dai, C., Li, J., Yong., J. (2016). Frequency-domain harmonic matrix model for three-phase diode-bridge rectifier. *IET Generation, Transmission and Distribution, 10* (*7*), 1605-1614. doi:1049/iet-gtd.2015.0871

Tokić, A., Jukan, A., Smajić, J. (2016). Parameter estimation of single-phase rectifier based loads: Analytical approach. *IEEE Transactions on Power Delivery, 31* (*2*), 532-540. doi:10.1016/j.tranpol.2016.01.013

Duenas, G. R., Riba, J. R., Eguilaz, M. M., Zuluaga, C. C. (2020). Non-intrusive parameter identification of a three-phase rectifier based on an optimization approach. *IECON Annual Conference of the IEEE Industrial Electronics Society,* 1389-1394. doi:10.1109/IECON43393.2020.9254824

6TH INTERNATIONAL CONFERENCE ENRE - ENERGY & RESPONSIBILITY
BOOK OF EXTENDED ABSTRACTS
S. Seme, K. Sredenšek (eds.)
University of Maribor Press

DEVELOPMENT OF AN EXPERIMENTAL SYSTEM FOR TESTING AN ELECTRIC DRIVE

LUKA ŽIVKOVIĆ, TIN BENŠIĆ, GORAN KURTOVIĆ, MARINKO BARUKČIĆ
University of Osijek, Faculty of Electrical Engineering, Computer Science and Information Technology, Osijek, Croatia
luka.zivkovic@ferit.hr, tin.bensic@ferit.hr, goran.kurtovic@ferit.hr, marinko.barukcic@ferit.hr

Keywords: electric motor, efficiency, control mode, frequency converter, torque limit

The impact of electric motors on electricity consumption and conversion in today's time is significant and can not be omitted. An experimental system has been developed in order to verify the characteristics of drives with electric motors. The experimental system consists of an induction motor, a synchronous reluctance motor, a frequency converter, and a PLC device. The system is intended for testing the characteristics of the induction motor, with the synchronous motor being used as the load machine. The frequency converter is controlled using the developed HMI interface. The synchronous motor is controlled by the frequency converter, and three motor control modes are enabled. Control is possible in Speed, Torque and Torque Limit modes of operation. The application of these three control modes gives the opportunity to test the drive under various conditions. The reference speed value of the synchronous motor is set in Speed mode. Direct control of the machine torque is carried out in Torque mode, with a reference torque value being specified. Torque Limit mode sets the reference speed value of the motor to zero, with defined limits on the torque that the motor may develop. Control of the induction motor is carried out using appropriate control techniques. The development of such an experimental system enables the implementation of different test procedures of electrical machines, with the purpose of comparing control methods.

References

Sandeep Anand, Rajesh Singh Farswan, and B. G. Fernandes (2012): Unique Power Electronics and Drives Experimental Bench (PEDEB) to Facilitate Learning and Research, IEEE Transactions on Education, 573 – 579, DOI: 10.1109/TE.2012.2200681

6TH INTERNATIONAL CONFERENCE ENRE - ENERGY & RESPONSIBILITY
BOOK OF EXTENDED ABSTRACTS
S. Seme, K. Sredenšek (eds.)
University of Maribor Press

SAMPLING INFLUENCE ON FERRORESONANCE SPECTRAL ANALYSIS

TIN BENŠIĆ, KRUNO MILIČEVIĆ, DAVOR VINKO, MARINKO BARUKČIĆ
Josip Juraj Strossmayer University Osijek, Faculty of Electrical Engineering, Computer Science and Information Technology, Osijek, Croatia
tin.bensic@ferit.hr, kruno.milicevic@ferit.hr, davor.vinko@ferit.hr, marinko.barukcic@ferit.si

Keywords: ferroresonance, nonlinear circuit, fourier transform, sampling time, ferroresonance experiment

The paper analyzes the influence of the sampling time and measured data decimation in a ferroresonance phenomena analysis. The ferroresonance phenomena are the bifurcation behavior of a nonlinear LC circuit supplied by external voltage.

In the literature, different steady states of ferroresonant nonlinear systems are identified by the harmonic content of the inductance and capacitance voltages and the circuit current, given a supply with sine voltage. The system`s sensitivity to voltage amplitude and harmonics change can invoke bifurcations into different steady states that limit the experimental ability to analyze the phenomena.

In order to analyze the phenomena, careful and accurate measurements are conducted in a laboratory on the existing experimental system, and the steady state Fourier analysis is conducted of the measured signals.

The Fourier analysis is influenced by the non-integer ratio of the analyzed waveform period to the sampling time, the number of samples in the measurement window, data decimation and measurement noise. These issues are addressed to analyze the measured waveforms in odd-harmonic, even-harmonic, sub-harmonic, and the more complex system steady.

Careful selection of the data points, decimation and zero crossing synchronization, reduces spectral leakage, and allows for the retrieval of information for specific harmonic components and their voltage dependence, especially in phase characteristics.

References

K. Miličević and Z. Emin, "Investigation of possible ferroresonance for a voltage range: realisation of a system event with a laboratory set-up," International Journal of Circuit Theory and Applications, vol. 41, no. 3, pp. 259272, Oct. 2011, doi: 10.1002/cta.797.

K. Milicevic, D. Pelin, and I. Flegar, "Measurement system for model verification of nonautonomous second-order nonlinear systems," Chaos, Solitons & Fractals, vol. 38, no. 4, pp. 939948, Nov. 2008, doi: 10.1016/j.chaos.2007.06.005.

T. Benšić, K. Miličević, D. Vinko and M. Barukčić, "Laboratory Experimental System for Ferroresonance Analysis," in Proceedings of Fourth International Conference on Smart Grid Metrology (SMAGRIMET 2023), J. Konjevod, A. Šala, and P. Mostarac, Eds., Cavtat: University of Zagreb, Faculty of Electrical Engineering and Computing, Apr. 2023, pp. 9195. doi: 10.1109/SMAGRIMET58412.2023.10128651.

6TH INTERNATIONAL CONFERENCE ENRE - ENERGY & RESPONSIBILITY
BOOK OF EXTENDED ABSTRACTS
S. Seme, K. Sredenšek (eds.)
University of Maribor Press

A CO-SIMULATION FRAMEWORK FOR MODELICA AND PYTHON: A CASE STUDY OF A SIMULATED TEST BENCH MODEL FOR ELECTRIC MOTORS AND DRIVES

GORAN KURTOVIĆ, LUKA ŽIVKOVIĆ, TIN BENŠIĆ, MARINKO BARUKČIĆ
University of Osijek, Faculty of Electrical Engineering, Computer Science and Information Technology, Osijek, Croatia
goran.kurtovic@ferit.hr, luka.zivkovic@ferit.hr, tin.bensic@ferit.hr, marinko.barukcic@ferit.hr

Keywords: co-simulation, modelica, python, test bench, electric motor, electric drive

Simulations allow the research and testing of different scenarios without actually implementing the system. This is especially useful in the development and design of electric motors and drives. However, Single-tool simulations might sacrifice accuracy due to simplifications or assumptions made during model creation. Complex real-world phenomena often require multidomain and co-simulations to capture all relevant effects accurately. Co-simulation is a technique that allows the integration of different simulation tools and platforms to create a unified simulation environment. Co-simulation can offer several benefits over single simulation, such as increased accuracy, reduced complexity and enhanced flexibility.

This paper presents a co-simulation framework for electric motors and drives using Modelica and Python. Modelica is used to model and simulate the test bench components, such as the electric motor, the power source and the load. Python is used to automate the simulation process, and to control the parameters and variables of the Modelica model. The effectiveness of the co-simulation approach is shown by comparing the results with a single-tool simulation using only Modelica. The challenges and limitations of co-simulation are also discussed, and some directions for future work are suggested, such as

adding more components to increase system complexity and extending the co-simulation framework to MATLAB/Simulink.

References

Leimeister, M. (2019). Python-Modelica Framework for Automated Simulation and Optimization. *13th International Modelica Conference, Proceedings*, 51-57. doi: 10.3384/ecp19157

Qin, D.C. et al. (JUL 2018). Modeling and Testing of the Multi-pole Field of a Motor for Pure Electric Vehicles. *Automotive innovation, Volume 1*, 226-236. doi:10.1007/s42154-018-0025-9

6TH INTERNATIONAL CONFERENCE ENRE - ENERGY & RESPONSIBILITY
BOOK OF EXTENDED ABSTRACTS
S. Seme, K. Sredenšek (eds.)
University of Maribor Press

SCENARIO ANALYSIS OF OPTIMAL PRODUCTION SCHEDULES CONSIDERING DIFFERENT OPTIMIZATION CONSTRAINTS

ADNAN GLOTIĆ, DEAN JUG, JERNEJ BRGLEZ, JANEZ SELAN,
PETER BEDENIK, MATJAŽ VEČERNIK, MATJAŽ EBERLINC

Holding Slovenske elektrarne, d.o.o., Ljubljana, Slovenia
adnan.glotic@hse.si, dean.jug@hse.si, jernej.brglez@hse.si, janez.selan@hse.si, peter.bedenik@hse.si, matjaz.vecernik@hse.si, matjaz.eberlinc@hse.si

Keywords: optimization, electrical energy production, trading, schedules, constraints

Siemens joint Resource Optimization and Scheduler (jROS or system) is used for managing the production portfolio covering various aspects of production and contracts with integrated data exchange between production and trading departments. In this article jROS is used to analyze the impact of different constraints and goals when scheduling the production of an HSE portfolio. As one can expect, the goals of different types of users/roles can easily be described as conflicting ones. However, to identify, objectively, how to extract the most value out of the production portfolio, we optimize the production against costs, as well as revenues, simultaneously. The most important goal is to maximize the difference between revenues and costs with respect to various imposed constraints (and their relaxations). In this paper we analyze the benefits of allowing overspill of water to maximize the available power of a hydro chain shortly, and thus increase revenues in peak market hours. The results are compared with scenarios where overspill is not allowed. Also, various cases of hydro reservoirs` constrains were analyzed, for instance, maintaining production with reservoirs nearly full.

6TH INTERNATIONAL CONFERENCE ENRE - ENERGY & RESPONSIBILITY
BOOK OF EXTENDED ABSTRACTS
S. Seme, K. Sredenšek (eds.)
University of Maribor Press

APPLICATION OF A FUNCTIONAL MOCKAP UNIT-FMU FOR SIMULATION ACCELERATION

MARINKO BARUKČIĆ, TIN BENŠIĆ, GORAN KURTOVIĆ, LUKA ŽIVKOVIĆ
University of Osijek, Faculty of Electrical Engineering, Computer Science and Information Technology, Osijek, Croatia
marinko.barukcic@ferit.hr, tin.bensic@ferit.hr, goran.kurtovic@ferit.hr, luka.zivkovic@ferit.hr

Keywords: FMU, real time simulations, simulation acceleration, engineering, optimization

For the last few decades, we have witnessed the huge involvement of simulation models of engendering areas, thanks to the simulation development and improvements in software, as well as hardware, tools. This has been emphasized in the last decade because of the fast development of artificial intelligence applications, especially involving concepts like smart grids, smart cities, Industry 4.0, and digital twins, all converging to the concept of a Smart Society. All these recent concepts require very fast and real-time simulations of engineering models in different phases, from system design, optimization, and on-site implementation. In recent years, the important role in the application of these modern concepts has required simulation models capable of performing different types of real-time simulations, like Hardver-in-the-Loop (HIL), Model/Softwer-in-the-Loop (M/SIL), and Rapide Control Prototyping (RCP). Beside this, the implementation of different computational intelligence optimization techniques requires hundreds or thousands of repetitions of model simulations. For such purpose, it is important to do simulations in real time, so the whole optimization process can be finished in some practically reasonable computational time. The Functional Mockup Unit (FMU) has been developed in the last few years to meet such requirements for very fast model simulations/calculations. The usage of FMU in recent times has become an Industrial Standard used by some eminent engineering companies.

References

on-line: https://fmi-standard.org/, Accesed on 18.03.2024.
on-line: https://fmi-standard.org/tools/, Accesed on 18.03

6TH INTERNATIONAL CONFERENCE ENRE - ENERGY & RESPONSIBILITY
BOOK OF EXTENDED ABSTRACTS
S. Seme, K. Sredenšek (eds.)

University of Maribor Press

THE ROLE OF SLEEP MODE IN MICROPROCESSOR-CENTRIC ELECTRONIC CIRCUIT DESIGN

DALIBOR IGREC, AMOR CHOWDHURY
University of Maribor, Faculty of Energy Technology, Krško, Slovenia
dalibor.igrec@um.si, amor.chowdhury@um.si

Keywords: energy management, sleep mode, microprocessor, electronic circuit design, efficiency

In electronic devices, which are governed by microprocessors, efficient energy management is crucial, especially in integrating sleep mode functionalities into electronic circuit design. Given the latency-dominated lifecycle of these devices, optimizing energy consumption is vital. Sleep mode, enabling microprocessors to enter a low-power state during inactivity, plays a crucial role in conserving energy and prolonging battery life, which is essential for portable devices.

The importance of sleep mode extends beyond enhancing user satisfaction by preserving battery longevity. It aligns with global sustainability efforts by reducing energy consumption and minimizing the environmental impact of electronic devices. This functionality not only benefits end-users but also addresses escalating environmental concerns. By reducing the power draw during periods of inactivity, sleep mode contributes to lower carbon footprints, aligning with eco-friendly practices and green technology trends.

Regulatory compliance also plays a significant role in the adoption of sleep mode. Many regions enforce strict energy efficiency standards, often necessitating the inclusion of sleep mode in electronic devices to meet these benchmarks. Compliance with these regulations ensures adherence to legal requirements and enhances market positioning.

The seamless transition between active and latent states, a hallmark of efficient sleep mode implementations, contributes significantly to a positive user experience. Despite extended periods of inactivity, users expect immediate responsiveness when devices are activated. Sleep mode achieves this by ensuring quick transitions without compromising device performance.

Incorporating sleep mode into electronic circuits containing microprocessors is not just a design consideration but a necessity. It significantly impacts device performance, longevity, sustainability, regulatory compliance, and user experience.

References

W. Ejaz, M. Naeem, A. Shahid, A. Anpalagan and M. Jo, "Efficient Energy Management for the Internet of Things in Smart Cities," in IEEE Communications Magazine, vol. 55, no. 1, pp. 84-91, January 2017, doi: 10.1109/MCOM.2017.1600218CM.

R. Chéour, S. Khriji, M. abid and O. Kanoun, "Microcontrollers for IoT: Optimizations, Computing Paradigms, and Future Directions," 2020 IEEE 6th World Forum on Internet of Things (WF-IoT), New Orleans, LA, USA, 2020, pp. 1-7, doi: 10.1109/WF-IoT48130.2020.9221219

H.Wu,C. Chen, K. Weng, An Energy-Efficient Strategy for Microcontrollers, Appl. Sci. 2021, 11(6), 2581; https://doi.org/10.3390/app11062581

R. Muralidhar, R. Borovica-Gajic, R. Buyya, Energy Efficient Computing Systems: Architectures, Abstractions and Modeling to Techniques and Standards, ACM Computing SurveysVolume 54Issue 11sArticle No.: 236pp 1–37https://doi.org/10.1145/3511094

6TH INTERNATIONAL CONFERENCE ENRE - ENERGY & RESPONSIBILITY
BOOK OF EXTENDED ABSTRACTS
S. Seme, K. Sredenšek (eds.)
University of Maribor Press

ACCURATE MODELLING OF MAGNETIC MATERIAL HYSTERESIS

MARKO JESENIK, ANTON HAMLER, MISLAV TRBUŠIĆ
University of Maribor, Faculty of Electrical Engineering and Computer Science, Maribor, Slovenia
marko.jesenik@um.si, anton.hamler@um.si, mislav.trbusic@um.si

Keywords: mathematical methods, material modelling, hysteresis, differential evolution, magnetic materials

Accurate models of the materials' characteristics are crucial when applied to the mathematical model of efficient electromagnetic devices. The Finite Element Method is often used for dimensioning of electromagnetic devices. The description of the magnetic materials should be as good as possible, so it is important that the nonlinear magnetic material is described with an accurate hysteresis model. Different hysteresis models have been developed in the past. The presented model is based on the measurement of the main hysteresis loop and first order reversal curves for increasing and decreasing magnetisation. Each of them is presented with an extended Elliots expression with six parameters. Each of the measured curves (the left and right parts of the major hysteresis curve and each of the first order reversal curves) has different parameters, obtained using Differential Evolution, and, with that, the best match was achieved between the measured and calculated curves. A good feature of the presented model is the easy calculation of magnetisation in the area where no measured curves are available. The curve between the measured curves can be determined based on only two points, and on the bases of the nearest calculated curve, obtained from the measured curve using Differential Evolution for the parameters` determination. The measured curves of the hard magnetic material AlNiCo (the main hysteresis loop and first-order reversal curves for increasing and decreasing magnetisation) are applied to the hysteresis model. A detailed description of the procedure will be presented in the final paper.

References

Petrescu, L., Cazacu, E., Petrescu, C. (2015). 9th International Symposium on Advanced Topics in Electrical Engineering, Bucharest, Romania, May 2015, 521-524.
Saruhan, H. (2014). Engineering Science and Technology, an International Journal, 17 (3), 131-136

6TH INTERNATIONAL CONFERENCE ENRE - ENERGY & RESPONSIBILITY
BOOK OF EXTENDED ABSTRACTS
S. Seme, K. Sredenšek (eds.)
University of Maribor Press

CONTROLLABILITY OF A DOUBLY FED INDUCTION GENERATOR

BOŠTJAN POLAJŽER,[1] ANNETTE MUETZE[2]

[1] University of Maribor, Faculty of Electrical Engineering and Computer Science, Maribor, Slovenia
bostjan.polajzer@um.si
[2] Graz University of Technology, Electric Drives and Power Electronic Systems Institute, Graz, Austria
muetze@tugraz.at

Keywords: doubly fed induction generator, variable speed, modal analysis, stability, controllability

Doubly Fed Induction Generators (DFIGs) have a wound rotor connected to a power converter (PC) through slip rings, while the stator is connected directly to the grid. Typically, a partially rated back-to-back PC provides voltages with variable amplitude and frequency; moreover, to operate at sub- and super-synchronous speeds, the PC should ensure a two-way energy flow. Due to the range of the variable speed operation, DFIGs are used as direct drives (low speed) in pumped hydropower plants, and as indirect drives (high speed with a gear box) in wind power plants. Both applications are reviewed in (Chen, 2021) and (Valavi, 2018). Unfortunately, a DFIG's dynamic behavior may show poorly damped modes with a natural frequency near the grid frequency (Rahimi, 2010) that cannot be controlled by the rotor voltages (Sadamoto, 2020).

This paper provides modal and controllability analyses of a DFIG by means of a d-q axis model. Different cases of model parameters are studied over the entire typical DFIG operating range of rotor speed and grid frequency variation. The result of the modal analysis shows a moderate impact of the model parameters on the eigenvalues, whereas it confirms low damping of two modes, which are related strongly to the rotor speed and grid frequency. Furthermore, the eigenvalues of the controllability Gramian matrix show

that both rotor and stator voltages should be controlled to enhance a DFIG's controllability.

References

Chen, H. et al. (2021). Modern electric machines and drives for wind power generation: A review of opportunities and challenges. *IET Renewable Power Generation*, *15(9),* 1–24, doi: 10.1049/rpg2.12114

Valavi, M., Nysveen, A. (2018). Variable-Speed Operation of Hydropower Plants: A Look at the Past, Present, and Future. *IEEE Industry Applications Magazine, 24(5)*, 18–27, doi: 10.1109/MIAS.2017.2740467

Rahimi, M., Parniani, M. (2010). Dynamic behavior analysis of doubly-fed induction generator wind turbines – The influence of rotor and speed controller parameters, *International Journal of Electrical Power and Energy Systems. 32,* 464–477, doi: 10.1016/j.ijepes.2009.09.017

Sadamoto, T., Chakrabortty, A. (2020). Improving Controllability and Plug-and-Play Operation of Wind Farms Using B2B Converters. *IEEE Control Systems Letters*, 4(2), 379–384, doi: 10.1109/LCSYS.2019.2931822

6TH INTERNATIONAL CONFERENCE ENRE - ENERGY & RESPONSIBILITY
BOOK OF EXTENDED ABSTRACTS
S. Seme, K. Sredenšek (eds.)

University of Maribor Press

SOME NOTES ON DESIGNING A SHELL-TYPE REACTOR

MISLAV TRBUŠIĆ, ANTON HAMLER, MARKO JESENIK
University of Maribor, Faculty of Electrical Engineering and Computer Science, Maribor, Slovenia
mislav.trbusic@um.si, anton.hamler@um.si, marko.jesenik@um.si

Keywords: short circuit reactance, inductance, FEM, optimisation, design

When designing large power transformers, ensuring sufficient short-circuit reactances between pairs of windings is an essential task. As a rule, this is achieved by selecting an appropriate geometry and constellation of windings within the transformer window. However, in some cases, such an approach is technically or economically unacceptable. In these cases, connecting a reactor in series with the winding is necessary. For low voltage level windings (e.g. 20 kV), a special shell-type reactor placed within the transformer's tank is used for this purpose. The paper deals with a shell-type reactor and the determination of the optimal design parameters, which implies a TOC (Transformer Ownership Cost) concept. The optimal design selection depends on the economically evaluated value of the unit, dictated by the losses, energy price and material costs. Since the geometry of the reactor is conditioned by the electrical losses and desired inductance, which, in turn, depend on the magnetic field distribution, it is necessary to use a computer-aided design (CAD) approach. The method presented in the paper relies on the numerical procedure, where the magnetic field is calculated using the Finite Element Method (FEM) based software FEMM 4.2, and the best solution is sought iteratively.

References

Bengtsson C. T., Kern J. A. (2020), Shunt reactors improve voltage stability and power quality, Transformers Magazine, vol. 7, no. 1, pp 78-82

Dolenc A. (1970). Transformatorji, Učbenik, Univerza v Ljubljani - Fakulteta za elektrotehniko, Ljubljana
Karsai K., Kerényi D., Kiss L., (1987). Large Power Transformers, Budapest: Académia Kiadó ABB (2007). Transformer handbook 3th ed.

6TH INTERNATIONAL CONFERENCE EnRe - ENERGY & RESPONSIBILITY
BOOK OF EXTENDED ABSTRACTS
S. Seme, K. Sredenšek (eds.)

University of Maribor Press

ANALYSIS OF ARC INTERRUPTION IN AC AND DC SWITCHING DEVICES

MARKO VODENIK, PETER KITAK, JANEZ RIBIČ

University of Maribor, Faculty of Electrical Engineering and Computer Science, Maribor, Slovenia
marko.vodenik1@um.si, peter.kitak@um.si, janez.ribic@um.si

Keywords: arc interruption, DC arc, AC arc, arc model, circuit breaker, switching devices

Switching devices are devices designed to make and/or break the current in electric circuits. With each switch manipulation, an arc may occur between the contacts of the switching device, which must be interrupted. Since both AC and DC currents are used in electrical networks, it is necessary to ensure that the arc is interrupted during the switching manipulation in both cases. In an AC current, the advantage of arc interruption is due to the natural zero crossing of the current. When the zero crossing of the current has occurred, the arc is always extinguished, and the interruption of the arc is enabled. The challenge of arc interruption with a DC current is due to no natural zero crossing of the current. When interrupting a DC arc, the increasing arc resistance increases the impedance of the circuit automatically, hence reducing the arc current. When the arc current is near zero crossing and the arc voltage is greater than the system voltage, the arc is extinguished, and the arc interruption is enabled. To determine the conditions for arc interruption of AC and DC currents, there are various models for determining the parameters of the arc. This analysis uses the arc model of Cassie and Mayr, who developed models for determining arc parameters analytically. Arc interruption analysis is performed for an AC and DC circuit breaker, which is one of the most important switching devices in power networks. The focus of this analysis is on determining the arc interruption of the DC current, as it is more difficult to perform.

References

Schavemaker, P.H. and Sluis, L. (2002). The Arc Model Blockset. *Proceedings of the Second IASTED International Conference, POWER AND ENERGY SYSTEMS (EuroPES)*,

Park K. H., Kwon I., Kwak Y. J. and Lee B. w. (2022). Evaluation of black-box arc model for DC circuit breaker and comparative analysis of arc characteristic parameters. *2022 6th International Conference on Electric Power Equipment - Switching Technology (ICEPE-ST),* 121-126. doi: 10.1109/ICEPE-ST51904.2022.9757120.

Slade P. G. (2014). Electrical contacts, principles and applications, second edition. *CRC Press,* International Standard Book Number-13: 978-1-4398-8131-6. doi: https://doi.org/10.1201/b15640

Flurscheim C. H. (1982). Power circuit breaker theory and design. *Peter Peregrinus Ltd., London, UK. IEE* Power Engineering Series 1. ISBN: 9780906048702. doi: 10.1049/PBPO001E

6TH INTERNATIONAL CONFERENCE EnRe - ENERGY & RESPONSIBILITY
BOOK OF EXTENDED ABSTRACTS
S. Seme, K. Sredenšek (eds.)
University of Maribor Press

AN INSIGHT INTO GRID-FOLLOWING AND GRID-FORMING CONTROL FOR INVERTER-BASED RESOURCES IN POWER SYSTEMS

MATEJ KERNDL, BOŠTJAN POLAJŽER
University of Maribor, Faculty of Electrical Engineering and Computer Science, Maribor, Slovenia
matej.kerndl@um.si, bostjan.polajzer@um.si

Keywords: grid-following, grid-forming, virtual inertia, inverter-based resources, power systems

As the world transitions to sustainable energy, traditional power plants equipped with synchronous generators are being replaced gradually by renewable energy sources, such as Inverter-Based Resources (IBRs), including solar and wind installations. While this shift is environmentally beneficial, it introduces challenges for maintaining voltage and frequency stability within power systems, due primarily to the gradual reduction of inertia that is traditionally provided by the rotating mass of synchronous generators (Tielens & Van Hertem, 2016). A prevalent control strategy implemented in most of today's IBRs is known as the grid-following (GFL) strategy. IBRs with GFL control act as current sources that synchronize with the grid voltage, commonly using a Phase-Locked Loop (PLL) unit. However, this control structure leads to instability issues in weak grids, due to their susceptibility to disturbances (Wang et al., 2020). A significant shortcoming of IBRs with GFL control is their inability to mimic the inertia of synchronous generators, prompting extensive research into new IBR control strategies that can emulate the characteristics of a synchronous machine, known as grid-forming (GFM) (Rathnayake et al., 2021).

This work focuses on providing readers, especially those new to this field, with a short insight into GFM and GFL methodologies of IBR control. We begin by describing the mathematical models of both control strategies and their characteristics. Secondly,

through simulations and analyses, we illustrate the effectiveness of GFM control in enhancing grid resilience and reliability, and, finally, we conclude by emphasizing the critical role of GFM control in the future of power systems.

References

Rathnayake, D. B., Akrami, M., Phurailatpam, C., Me, S. P., Hadavi, S., Jayasinghe, G., Zabihi, S., & Bahrani, B. (2021). Grid Forming Inverter Modeling, Control, and Applications. *IEEE Access*, *9*, 114781-114807. https://doi.org/10.1109/access.2021.3104617 https://www.siemens-energy.com/global/en/offerings/power-generation/gas-turbines/sgt-800.html

6TH INTERNATIONAL CONFERENCE EnRe - ENERGY & RESPONSIBILITY
BOOK OF EXTENDED ABSTRACTS
S. Seme, K. Sredenšek (eds.)

University of Maribor Press

HARDWARE IN THE LOOP TESTING OF A PROTECTION MONITORING AND DIAGNOSTIC SYSTEM

JERNEJ ČERNELIČ,[1] BOŠTJAN POLAJŽER,[1] JANEZ ZAKONJŠEK,[2]
ALEXEY NEBERA,[3] GORAZD HROVAT[4]

[1] University of Maribor, Faculty of Electrical Engineering and Computer Science, Maribor, Slovenia
jernej.cernelic@um.si bostjan.polajzer@um.si
[2] Relarte d.o.o., Bohinjska Bistrica, Slovenia
janez.zakonjsek@relarte.com
[3] Kontron d.o.o., Kranj, Slovenia
alexey.nebera@kontron.si
[4] ELES d.o.o., Ljubljana, Slovenia
gorazd.hrovat@eles.si

Keywords: protection, monitoring, analysis, disturbance records, event tree

The reliability of electric power systems (EPS) depends on protection, automation and control (PAC) devices. In North American EPS, for example, the rate of protection device misoperation is between 6 and 7 %, where around 50 % of all misoperations are caused by incorrect settings and relay malfunctions (NERC, 2021). Modern PAC devices provide information about their software and hardware settings and the conditions of external circuits. However, it is challenging to gather all the information, because of the high number of PAC devices and the high diversity of information between different software versions and device types.

Analysing disturbance records, as critical information, is a complex and time-consuming process that is rarely implemented for a full set of involved devices. The protection monitoring and diagnostic (PMD) system can be used to gather and synchronise the disturbance records from different sources, such as protection relays, fault recorders and

SCADA systems. The PMD system can then analyse the correctness of each protection function operation automatically by analysing the event tree (Horowitz, 2003 and Zhang, 2004). This work will present the PMD system testing. A hardware-in-the-loop configuration will be used, including two distance protection relays connected to the PMD and the real-time digital simulator, which will simulate different fault scenarios in a modelled power system. The simulation model will be limited to the observed transmission line and equivalent sources. The results will show how PMD can obtain the disturbance records and provide the event tree report, thus reducing the protection specialist's workload.

References

Horowitz et al. (Sep. 2003). Boosting Immunity to Blackouts. IEEE Power Energy Mag., 1(5): 47-53

North American Reliability Corporation NERC, (2021), State of Reliability, An Assessment of 2020 Builk Power System Performance, www.nerc.com

Zhang N. et al (2004) Verifying the Protection Operation Using an Advanced Fault Analysis Tool Combined with the Event Tree Analysis, Northern American Symposium (NAPS).

6TH INTERNATIONAL CONFERENCE ENRE - ENERGY & RESPONSIBILITY
BOOK OF EXTENDED ABSTRACTS
S. Seme, K. Sredenšek (eds.)

University of Maribor Press

REDUCING THE UNCERTAINTY OF CARBON FOOTPRINT CALCULATIONS WITH A DYNAMIC MODEL OF ELECTRICITY'S CARBON FOOTPRINT

DOMEN HOJKAR, ROK STROPNIK, MITJA MORI
University of Ljubljana, Faculty of Mechanical Engineering, Ljubljana, Slovenia
domen.hojkar@fs.uni-lj.si, rok.stropnik@fs.uni-lj.si, mitja.mori@fs.uni-lj.si

Keywords: Carbon footprint, electricity dynamics, carbon intensity, dynamic carbon footprint model, decarbonization, GHG emissions

A carbon footprint (CF), which measures the amount of greenhouse gases (GHG) caused by a certain activity, is becoming a key indicator in the fight against climate change. To achieve climate neutrality, it is important to ensure methodological and accurate measurements of CF, since understanding its impacts on the environment is a basis for targeting climate change mitigation efforts.

Electricity consumption is a major contributor to global CF, and it will play a pivotal role in achieving ambitious GHG reduction goals (Williams et al., 2012). The carbon intensity of electricity depends on the generation technology (Turconi et al., 2013). The current practice is to calculate emissions from electricity use by using the average yearly carbon intensities. However, as electricity generation is dynamic, electricity from the grid has a varying carbon intensity at any moment, and the time dynamics need to be included in environmental analyses (Khan, 2018).

We show that using yearly averages for carbon intensity is only appropriate for processes that have a stable consumption profile throughout the year. Whereas, if the analyzed process has a different dynamic (e.g., shift working, seasonal/monthly production) the uncertainty of the CF calculation increases.

Our research developed a dynamic CF model for electricity consumption in Slovenia. We show that including the time dynamics of electricity consumption in CF calculations is important for reducing uncertainty. Hourly or 15-minute electricity generation and consumption dynamics need to be modeled for the most accurate CF calculations. Understanding CF time dynamics also opens the door for demand-side management and reduction of GHG emissions.

References

Khan, I. (2018). Importance of GHG emissions assessment in the electricity grid expansion towards a low-carbon future: A time-varying carbon intensity approach. *Journal of Cleaner Production*, *196*, 1587–1599. https://doi.org/10.1016/J.JCLEPRO.2018.06.162

Turconi, R., Boldrin, A., & Astrup, T. (2013). Life cycle assessment (LCA) of electricity generation technologies: Overview, comparability and limitations. *Renewable and Sustainable Energy Reviews*, *28*, 555–565. https://doi.org/10.1016/J.RSER.2013.08.013

Williams, J. H., DeBenedictis, A., Ghanadan, R., Mahone, A., Moore, J., Morrow, W. R., Price, S., & Torn, M. S. (2012). The technology path to deep greenhouse gas emissions cuts by 2050: The pivotal role of electricity. *Science*, *335*(6064), 53–59. https://doi.org/10.1126/SCIENCE.1208365

6TH INTERNATIONAL CONFERENCE EnRe - ENERGY & RESPONSIBILITY
BOOK OF EXTENDED ABSTRACTS
S. Seme, K. Sredenšek (eds.)
University of Maribor Press

AGROVOLTAICS IN SLOVENIA: REGULATORY FRAMEWORK, SPATIAL REQUIREMENTS AND POTENTIAL LOCATIONS

KLEMEN SREDENŠEK,[1] EVA SIMONIČ,[1] SEBASTIJAN SEME[1,2]

[1] University of Maribor, Faculty of Energy Technology, Krško, Slovenia
eva.simonic@um.si, klemen.sredensek@um.si, sebastijan.seme@um.si
[2] University of Maribor, Faculty of Electrical Engineering and Computer Science, Maribor, Slovenia
sebastijan.seme@um.si

Keywords: agrovoltaics, spatial requirements, potential locations, agricultural land, photovoltaic systems

This paper presents an in-depth examination of the regulatory framework, spatial prerequisites for optimal placement on agricultural lands, and an evaluation of potential locations for agrovoltaics in Slovenia. Agrovoltaics, a synergistic integration of agriculture and photovoltaic energy production, aims at enhancing resource efficiency and sustainability. This innovative approach promises mutual benefits for energy and agriculture, aligning with multiple policy sectors, including energy, agriculture, environmental protection, the circular economy, alongside research and innovation. Such alignment is instrumental in advancing the goals of the European Green Deal, which aspires to attain climate neutrality in the EU by 2050, stimulate the economy through green technology, foster sustainable industries and transport systems, and minimize pollution levels.

Following the enactment of a new legislation on August 3, 2023, which facilitates the adoption of renewable energy source systems, Slovenia has taken preliminary steps toward embracing agrovoltaics. This paper aims to delineate the specific agricultural lands eligible for agrovoltaic installations, outline the technical constraints (e.g., installation height,

foundation requirements), navigate through spatial planning and limitations, and provide a strategic analysis of potential agricultural locations for agrovoltaic placement. Through this investigation, the paper seeks to contribute to the body of knowledge on agrovoltaics in Slovenia, underlining its potential in supporting sustainable agricultural practices and renewable energy production within the ambit of the European Green Transition objectives.

References

Act on the introduction of devices for the production of electricity from renewable energy sources (Official Gazette of the Republic of Slovenia, No. 78/23)

European Green Deal; available at: https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en; [access attempt 6 . 3. 2024].

Trommsdorff M., Gruber S., Keinath, T., Hopf M., Hermann C., Schönberger F., Zikeli S., Ehmann A., Weselek A., Bodmer U., et al. (2022), Agrivoltaics: Opportunities for Agriculture and the Energy Transition. Fraunhofer Institute for Solar Energy Systems ISE, 2nd ed.; Fraunhofer Institute for Solar Energy Systems ISE Heidenhofstrasse 2: Freiburg, Germany.

Katsikogiannis O.A., Ziar H., Isabella O. (2022), Integration of bifacial photovoltaics in agrivoltaic systems: A synergistic design approach, Appl. Energy, vol. 309, pp 118475.

6TH INTERNATIONAL CONFERENCE ENRE - ENERGY & RESPONSIBILITY
BOOK OF EXTENDED ABSTRACTS
S. Seme, K. Sredenšek (eds.)
University of Maribor Press

REVIEW AND UPDATE OF KEY LEARNING CONTENTS, KNOWLEDGE, SKILLS AND EXPECTED LEARNING OUTCOMES FOR A SUSTAINABLE GREEN TRANSITION

SONJA KRAJNC, BOJAN ŠTUMBERGER
University of Maribor, Faculty of Energy Technology, Krško, Slovenia
sonja.krajnc@um.si; bojan.stumberger@um.si

Keywords: sustainable green transition, digital transformation, sustainable development, energy poverty, sustainable energy

The Faculty of Energy Technology of the University of Maribor has obtained a pilot project successfully, "Review and update of key learning contents, knowledge, skills, and expected learning outcomes for a sustainable green transition," within the framework of The Recovery and Resilience Plan (RRP).

The activities of the pilot project are focused primarily on the transformation of the set of all elective courses, where, according to the existing regulatory framework, a faster dynamic of transformation is expected (1-2 years). For most elective courses, e-materials will be prepared, the most suitable teaching methods proposed, and the set of expected and recognized subject-specific professional competencies will be supplemented with appropriate records of learning outcomes, which will be more easily understandable to students, prospective students, employers, and representatives of professional associations.

The updated curricula have implemented the contents of the European Competence Framework for Sustainability, with the aim of promoting sustainable thinking in a way that helps those involved in the learning process develop knowledge, understanding, skills, and attitudes that will develop a comprehensive valuation of sustainability, systems thinking, critical thinking, problem formulation, literacy for the future, and research thinking.

In the updated curricula, learning outcomes are used for a better understanding and description of competencies, defining clearly what the student should achieve, and how they should demonstrate their learning achievements.

The content of the updated curricula pursues primarily the following sustainable development goals: elimination of energy poverty, inclusive quality education, ensuring access to affordable, reliable, sustainable, and modern energy, and ensuring sustainable patterns of energy consumption and production.

6TH INTERNATIONAL CONFERENCE ENRE - ENERGY & RESPONSIBILITY
BOOK OF EXTENDED ABSTRACTS
S. Seme, K. Sredenšek (eds.)
University of Maribor Press

DYNAMIC MODELING OF AN IRON CORE INDUCTOR AND ELECTROMAGNETIC BRAKE

IZTOK BRINOVAR,[1] ZDRAVKO PRAUNSEIS,[1] AMOR CHOWDHURY,[1,2]
BOJAN ŠTUMBERGER,[1,3] MIRALEM HADŽISELIMOVIĆ[1,3]

[1] University of Maribor, Faculty of Energy Technology, Krško, Slovenia
iztok.brinovar@um.si, zdravko.praunseis@um.si, amor.chowdhury@um.si, bojan.stumberger@um.si, miralem.h@um.si
[2] University of Ljubljana, Faculty of Mechanical Engineering, Ljubljana, Slovenia
ameramor.chowdhuryhaque@fs.uni-lj.si
[3] University of Maribor, Faculty of Electrical Engineering and Computer Science, Maribor, Slovenia
bojan.stumberger@um.si, miralem.h@um.si

Keywords: dynamic model, electromagnetic brake, inductor, finite element method, magnetic flux linkage

Mathematical models serve a pivotal role in electrical engineering, particularly in the analysis, design, control, and optimization of electric machines and devices. These models are constructed carefully using mathematical equations to capture the system dynamics. Two simplifications are commonly considered when modeling electric machines and devices, covering iron losses and iron's nonlinear magnetic properties. Simplified models are more robust but less precise, while models considering magnetic nonlinearities are more complex and accurate. This article deals with the dynamic modeling of an iron core inductor and electromagnetic brake. In the first part, the article discusses the design of an iron-core inductor dynamic model with experimentally based determination of its parameters. Dynamic responses for both a nonlinear and linearized model are presented, along with experimental evaluation. In the second part, the article discusses the design of an electromagnetic brake dynamic model. The current and position-dependent magnetic flux linkage and electromagnetic force characteristics of the electromagnetic brake are determined numerically using the finite element method. Additionally, the article addresses

the experimental evaluation of the dynamic model and numerically determined characteristics of the electromagnetic brake.

References

Nana, B., Woafo, P. (2015). Simple mathematical model for ferromagnetic core inductance and experimental validation. *American Journal of Electrical Engineering*, Vol. 3, No. 2, 29-36. doi:10.12691/ajeee-3-2-2

Hadžiselimović, M., Virtič, P., Štumberger, G., Marčič, T., Štumberger, B. (2008). Determining force characteristics of an electromagnetic brake using co-energy. *Journal of Magnetism and Magnetic Materials*, Vol. 320, No. 20, 556-551. doi:10.1016/j.jmmm.2008.04.013

Brinovar, I., Srpčič, G., Štumberger, B., Hadžiselimović, M., Seme, S. (2019). Numerical analysis of the electromagnetic brake. *Przegląd Elektrotechniczny*. Vol. 95, No. 1, 1-3. doi:0.15199/48.2019.01.01

6TH INTERNATIONAL CONFERENCE ENRE - ENERGY & RESPONSIBILITY
BOOK OF EXTENDED ABSTRACTS
S. Seme, K. Sredenšek (eds.)
University of Maribor Press

HARMONIC MITIGATION STRATEGIES FOR GRID INTEGRATED PV SYSTEMS

FRANJO PRANJIĆ, PETER VIRTIČ
University of Maribor, Faculty of Energy Technology, Krško, Slovenia
franjo.pranjic@um.si, peter.virtic@um.si

Keywords: harmonic, harmonic filters, inverters, distributed generation, power quality

Harmonics are electrical waveforms that have frequencies that are integer multiples of the fundamental frequency. Harmonics occur when additional frequencies, known as harmonic frequencies, are present alongside the fundamental frequency.

As the number of distributed generation (DG) units, relying primarily on renewable energy sources, increases and connects to utility power grids, maintaining power quality emerges as a significant challenge. Harmonics originating from DG units, particularly those generated by power electronic devices like photovoltaic systems, contribute to this concern. In order to maintain a suitable power quality, harmonic mitigation strategies are essential, since harmonics can affect both the PV system itself and the broader electrical grid negatively.

The article presents an overview of the harmonic mitigation strategies for grid-integrated PV systems, such as: Passive Harmonic Filters; Active Harmonic Filters; Multi-Level Inverters; Advanced Inverter Control Strategies; Transformer Design and Configuration; Voltage Source Converters (VSCs); Resonance Avoidance; Filtering at Point of Common Coupling (PCC); Hybrid Harmonic Mitigation and Monitoring and Maintenance.

References

L. Lin, Q. Jia, C. Lv, J. Liang and P. Luo, "Partitional Collaborative Mitigation Strategy of Distribution Network Harmonics Based on Distributed Model Predictive Control," in IEEE Transactions on Smart Grid, vol. 14, no. 3, pp. 1998-2009, May 2023, doi: 10.1109/TSG.2022.3211008.

R. K. Varma, S. A. Rahman, T. Vanderheide and M. D. N. Dang, "Harmonic Impact of a 20-MW PV Solar Farm on a Utility Distribution Network," in IEEE Power and Energy Technology Systems Journal, vol. 3, no. 3, pp. 89-98, Sept. 2016, doi: 10.1109/JPETS.2016.2550601.

L. Zhang, W. Hong, C. Gao, R. Liu, Q. Yu and C. Wei, "Selected Harmonic Mitigation PWM Power Matching Control Strategy for Asymmetric Cascaded H-Bridge Multilevel Inverter," in IEEE Journal of Emerging and Selected Topics in Power Electronics, vol. 10, no. 4, pp. 4059-4072, Aug. 2022, doi: 10.1109/JESTPE.2021.3137337.

M. K. Mishra and V. N. Lal, "An Advanced Proportional Multiresonant Controller for Enhanced Harmonic Compensation With Power Ripple Mitigation of Grid-Integrated PV Systems Under Distorted Grid Voltage Conditions," in IEEE Transactions on Industry Applications, vol. 57, no. 5, pp. 5318-5331, Sept.-Oct. 2021, doi: 10.1109/TIA.2021.3091046.

<EnRe>
energy & responsibility

RENEWABLE ENERGY SOURCES, STORAGE, AND ENERGY MANAGEMENT

6TH INTERNATIONAL CONFERENCE ENRE - ENERGY & RESPONSIBILITY
BOOK OF EXTENDED ABSTRACTS
S. Seme, K. Sredenšek (eds.)

University of Maribor Press

STUDY OF AN OFF-GRID HOUSEHOLD POWERED BY SOLAR AND HYDROGEN ENERGY

FRANCO KROG,[1] URŠKA NOVOSEL[2]

[1] University of Maribor, Faculty of Energy Technology, Krško, Slovenia
franco.krog@student.um.si
[2] University of Maribor, Faculty of Energy Technology, Krško, Slovenia
urska.novosel@um.si

Keywords: hydrogen, sustainability, solar energy, off-grid household, renewable energy

In this article, we will perform a study of an off-grid household that uses solar and hydrogen energy as its primary energy source. In an era marked by environmental consciousness and the pursuit of energy independence, off-grid households are turning increasingly to innovative solutions to meet their power needs sustainably.

The concept is an off-grid household that uses solar panels as the primary electrical energy source, and, in times without solar energy, it uses hydrogen fuel cells as an electrical energy source by using hydrogen that the solar power plant produced by using excess energy throughout a year. However, challenges persist in matching supply with demand and ensuring uninterrupted power availability. By combining solar power and hydrogen technologies, off-grid households can achieve greater energy resilience and reduce reliance on traditional fossil fuels. This article examines the technical feasibility, economic viability, environmental benefits of such integrated systems, highlighting their potential to revolutionise off-grid living and pave the way towards a sustainable energy future. The goals we want to determine are how much hydrogen we need, what size hydrogen tanks we need, how powerful the solar plant should be, and a feasibility study of the financial investment and savings.

References

Ofélia Q. F. Araújo1 · José Luiz de Medeiros, Hydrogen in the energy transition: some roles, issues, and questions, Clean Technologies and Environmental Policy , August 2023

A. S. Tijani, N. A. B. Kamarudin, F. A. B Mazlan, Investigation of effect of charge transfer coefficient (CTC) on the operating voltage of polymer electrolyte memberane (PEM) electrolyzer, International Journal of Hydrogen Energy, April 2018

D. Brezak, A. Kovač, M. Firak, Matlab/Simulink simulation of low-pressure PEM electrolyzer stack, Faculty of Mechanical Engineering and Naval Architecture, University of Zagreb, Croatia

Zhang, L., Zhao, H., Wilkinson, D. P., Sun, X., & Zhang, J. (Eds.). (2020). Electrochemical Water Electrolysis: Fundamentals and Technologies

Rahim AHA, Tijani AS, Shukri FH, Hanapi S, Sainan KI.Mathematical modelling and simulation analysis of PEM electrolyzer system for hydrogen production. IET; 2014, 2015; CEAT

Kumar, S. S., & Himabindu, V. (2019). Hydrogen production by PEM water electrolysisA review. Materials Science for Energy Technologies, 2(3), 442-454

H. Lee, S. Lee, Economic Analysis on Hydrogen Pipeline Infrastructure Establishment Scenarios: Case Study of South Korea, Department of Climate and Energy Systems Engineering, Seoul 03760, Korea

6TH INTERNATIONAL CONFERENCE ENRE - ENERGY & RESPONSIBILITY
BOOK OF EXTENDED ABSTRACTS
S. Seme, K. Sredenšek (eds.)
University of Maribor Press

CHALLENGES OF SIMULATION-DRIVEN HIGH-RESOLUTION LAND SURFACE TEMPERATURE ESTIMATION IN URBAN ENVIRONMENTS

NIKO LUKAČ, GORAZD ŠTUMBERGER, PRIMOŽ SUKIČ, JURČEK VOH, MARKO BIZJAK

University of Maribor, Faculty of Electrical Engineering and Computer Science, Maribor, Slovenia
niko.lukac@um.si, gorazd.stumberger@um.si, p.sukic@um.si, jurcek.voh@um.si, m.bizjak@um.si

Keywords: land surface temperature, remote sensing data, simulations, modelling, LiDAR

In recent years, the amount of remote sensing data, such as satellite imagery and laser scanning, has increased immensely, allowing for new environmental simulations and modeling approaches over high-resolution geospatial areas. One of the key technologies enabling this is airborne LiDAR (Light Detection and Ranging) laser scanning, providing high-resolution 3D capture of large geographic areas. This enables new applications for energy modeling, especially for energy resource assessment and spatial planning (Avtar, 2019). In recent years, various simulation approaches have been developed for estimating high-resolution solar potential (Lukač, 2023), wind potential (Lukač, 2017), and other renewable energy sources over specific geographic locations. One of the challenges in understanding the urban climate is the accurate estimation of land surface temperature (LST), as well as air temperature, over high-resolution geospatial data (Hofierka, 2022). There are many challenges ahead for accurate LST estimation, especially regarding remote sensing data (e.g., preprocessing, missing data, availability, inaccuracies, noise, etc.) and the aspects of deep learning or physical models used in analytical simulations (e.g., computational complexity, assumptions, validation, etc.). Our finding is that now is just

the right time to solve these challenges in an accurate and efficient manner, as the amount of heterogeneous data is sufficient, and the rise of high-performance computing has enabled more complex physical models to be used within simulations over geospatial data. New methods for accurate estimation of LST provide new applications for urban planning (e.g., mitigation of urban heat islands) and energy modeling (e.g., thermal panels).

References

R. Avtar, N. Sahu, A.K. Aggarwal, S. Chakraborty, S., et al. (2019), Exploring renewable energy resources using remote sensing and GIS—A review. *Resources*, 8 (3), 149. doi: 10.3390/resources8030149

N Lukač, D Mongus, B Žalik, G Štumberger, M Bizjak (2023), Novel GPU-accelerated high-resolution solar potential estimation in urban areas by using a modified diffuse irradiance model. *Applied Energy* 353, 122129. doi: 10.1016/j.apenergy.2023.122129

N Lukač, G Štumberger, B Žalik (2017), Wind resource assessment using airborne LiDAR data and smoothed particle hydrodynamics. *Environmental Modelling & Software* 1, 1-12. doi: doi.org/10.1016/j.envsoft.2017.05.006

J. Hofierka (2022). Assessing Land Surface Temperature in Urban Areas Using Open-Source Geospatial Tools. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences.* 48, 195-200.

6TH INTERNATIONAL CONFERENCE ENRE - ENERGY & RESPONSIBILITY
BOOK OF EXTENDED ABSTRACTS
S. Seme, K. Sredenšek (eds.)

University of Maribor Press

PRACTICAL EXPERIENCE IN THE DYNAMIC MANAGEMENT OF A SOLAR POWER PLANT

BORIS TURHA
Elektro Ljubljana (DSO), Ljubljana, Slovenia
boris.turha@elektro-ljubljana.si

Keywords: dynamic management, solar power plant, DSO, state estimator, ADMS

Because of long LV feeders, MV/LV transformer tap changers are set higher to compensate for voltage drops, making it difficult to connect many photovoltaic power (PV) plants, due to voltage increases during peak generation. Due to the structure of the LV network, even the use of MV/LV transformers with automatic underload tap changers (ULTC) often doesn't help much and is very costly. Therefore, we are developing a system that will enable us to connect more PV plants to the LV network, with occasional limitations in generation.

The paper presents a real-life case of dynamic generation control of a PV plant connected to an LV network, and the development of a system that controls RES generation based on close-to-real-time measurement of voltage at a critical point of the network and cloud-based connections. The analysis is presented of a one-year operation in such a regime. The results, which will be presented, demonstrated huge potential to increase PV generation on the national level, with only minor curtailment and a very small investment. Also, some economic effects will be presented.

Further development of a system will be presented, based on the voltage estimated by the state estimator, avoiding the need for any additional online measurements. State estimation in the Advanced Distribution Management System (ADMS) estimates the current state of the distribution network (voltages, currents, and loading) at all nodes. It considers

measurements from various devices, to calculate the state variables of the system. These will be the basis for the decision to reduce the generation of any PV plant connected to a particular LV feeder.

References

Internal DSO reports.

6TH INTERNATIONAL CONFERENCE EnRe - ENERGY & RESPONSIBILITY
BOOK OF EXTENDED ABSTRACTS
S. Seme, K. Sredenšek (eds.)
University of Maribor Press

HOUSEHOLDS' ELECTRICITY CONSUMPTION FROM SMART METERS IN SLOVENIA FOR THE PERIOD 2020-2023

KLEMEN DEŽELAK
Statistical Office of the Republic of Slovenia (SURS), Environment and Energy Statistics Section, Ljubljana, Slovenia
klemen.dezelak@gov.si

Keywords: smart meters, electricity consumption, households, distribution grid, advanced metering system

The Advanced Metering Implementation Plan within the electrical distribution system of Slovenia from the year 2016 represented a document that provided a plan for the introduction of an advanced measurement system, as specified in the Measures and Procedures Regulation from year before. In 2016, 45% of the measuring points had already been equipped with the system counters, but the level of advanced services had not yet been at an acceptable level. At that point, the development of more advanced technological and personal protection solutions required verification and updating of the proposed guidelines as well. After six years, we can say that Slovenia ranks among the leading European countries related to installing advanced measuring devices. At the end of 2022, 91.9% of users on the distribution system were already equipped with advanced metering devices, while 89.2% were actually connected to the remote capture of measurement data. A Distribution System Operator operates with data, accurate to the measuring point, on a monthly basis, and these are linked to data on the location. The data in the distribution system operator database reflect the situation for the whole of Slovenia, as they include data measured with the help of smart meters, and flat-rate data that are calculated annually. Households` electricity consumption from smart meters in Slovenia for a 4 year period (2020-2023) is dealt with in the work.

References

Decree on measures and procedures for the introduction and interoperability of advanced electric power metering systems. (2015). Uradni list RS, št. 79/15 in 172/21 – ZOEE, 2015

Zakon o oskrbi z električno energijo (ZOEE). (2021). Uradni list RS, št. 172/21, dne 29. 10. 2021

Načrt uvedbe naprednega merilnega sistema v elektrodistribucijskem sistemu Slovenije. (2016). SODO ID 1566, Sistemski operater distribucijskega omrežja z električno energijo, d.o.o., Maribor, 2016

Poročilo o stanju na področju energetike v Sloveniji 2022. (2023). Agencija za energijo, Maribor, 2023

6TH INTERNATIONAL CONFERENCE EnRe - ENERGY & RESPONSIBILITY
BOOK OF EXTENDED ABSTRACTS
S. Seme, K. Sredenšek (eds.)
University of Maribor Press

PERFORMANCE OPTIMIZATION OF THE PHOTOVOLTAIC/THERMAL SYSTEM

KLEMEN SREDENŠEK,[1] EVA SIMONIČ,[1] SEBASTIJAN SEME[1,2]

[1] University of Maribor, Faculty of Energy Technology, Krško, Slovenia
eva.simonic@um.si, klemen.sredensek@um.si, sebastijan.seme@um.si
[2] University of Maribor, Faculty of Electrical Engineering and Computer Science, Maribor, Slovenia
sebastijan.seme@um.si

Keywords: photovoltaic/thermal system, optimization, electrical energy, waste heat, cooling mechanisem

This paper presents a comprehensive analysis of optimizing the performance of a photovoltaic/thermal system installed at the Institute of Energy Technology, Faculty of Energy Technology, University of Maribor. With the advent of commercial photovoltaic systems taking a pivotal role as prime units for generating electricity from renewable sources, the market has witnessed the emergence of several innovative photovoltaic system products. These products leverage diverse cooling methodologies aimed at enhancing their operational efficacy. Among such innovations is the so-called photovoltaic/thermal system, distinguished by its cooling mechanism, which not only facilitates superior electrical energy production compared to standard commercial photovoltaic systems, but also, concurrently, generates a portion of thermal energy by harvesting the heat extracted from the system itself. The optimal functionality of this system is contingent upon an integrated setup comprising photovoltaic/thermal modules, thermal energy storage, and the requisite electrical and mechanical infrastructure. A pivotal component for the system's operation includes circulation pumps, which are instrumental in modifying the coolant's flow rate, thereby ensuring efficient management of both electrical and thermal energy production. The primary objective of this paper is to delineate an optimization strategy for maximizing the electrical or thermal energy output of the aforementioned photovoltaic/thermal system, employing a sophisticated

optimization algorithm. This entails a thorough examination of the system's design parameters, operational dynamics, and the implementation of an algorithm capable of identifying optimal operational configurations, thereby enhancing the system's overall performance and energy yield significantly.

References

Hosseinzadeh M., Salari A., Sardarabadi M., Passandideh-Fard M. (2018), Optimization and parametric analysis of a nanofluid based photovoltaic thermal system: 3D numerical model with experimental validation, Energy Conversion and Management vol. 160, pp 93–108.

Kazemian A., Parcheforosh A., Salari A., Ma T. (2021) Optimization of a novel photovoltaic thermal module in series with a solar collector using Taguchi based grey relational analysis, Solar Energy, vol. 215, pp 492–507.

Sobhnamayan F., Sarhaddi F., Alavi M. A., Farahat S., Yazdanpanahi J. (2014), Optimization of a solar photovoltaic thermal (PV/T) water collector based on exergy concept, Renewable Energy, vol. 68, pp 356–365.

Thakare M. S., Krishna Priya G. S., Ghosh P. C. (2016), Bandyopadhyay, S. Optimization of photovoltaic-thermal (PVT) based cogeneration system through water replenishment profile., Solar Energy vol. 133, pp 512–523.

6TH INTERNATIONAL CONFERENCE ENRE - ENERGY & RESPONSIBILITY
BOOK OF EXTENDED ABSTRACTS
S. Seme, K. Sredenšek (eds.)
University of Maribor Press

IDENTIFICATION AND EVALUATION OF IMPLICIT AND EXPLICIT FLEXIBILITY MECHANISMS FOR HOUSEHOLD ENERGY MANAGEMENT

EVA TRATNIK, MILOŠ BEKOVIĆ
University of Maribor, Faculty of Electrical Engineering and Computer Science, Maribor, Slovenia
eva.tratnik@um.si, milos.bekovic@um.si

Keywords: active user, battery energy storage system, case study, implicit flexibility, explicit flexibility

This paper focuses on the identification and evaluation of implicit and explicit flexibility mechanisms that household users can employ for effective energy management. Implicit flexibility mechanisms refer to automated or algorithm-driven responses of household devices or systems to changes in energy prices, grid conditions, or user preferences. On the other hand, explicit flexibility mechanisms involve user-initiated actions or decisions, aimed at optimizing energy consumption and cost savings.

The study first delves into the development of autonomous decision-making logic for flexibility mechanisms, emphasizing the importance of creating algorithms or frameworks that enable devices to adjust their operations autonomously. Subsequently, it evaluates the benefits of employing both implicit and explicit flexibility mechanisms on various performance indicators, such as energy consumption, cost savings, etc.

By assessing the impact of flexibility mechanisms on these indicators, active users gain insights into the potential advantages and trade-offs associated with different strategies. For example, the implementation of demand response programs may lead to reduced peak loads on the grid and lower electricity costs for active users, but may also require users to

relinquish some control over their devices, or adjust their behavior in response to external signals.

Overall, the paper contributes to the understanding of how implicit and explicit flexibility mechanisms can optimize energy use and promote sustainability in residential settings. It provides valuable insights for active users to make informed decisions about energy management strategies, and advance the development of more efficient and resilient energy systems in households.

References

Agencija za energijo, Neodvisni agregator na slovenskih trgih električne energije -aktualni vidiki. *Posvetovalni dokument* 2020.

Beyza, J.; Yusta, J. M., The effects of the high penetration of renewable energies on the reliability and vulnerability of interconnected electric power systems. *Reliability Engineering & System Safety* 2021, 215. http://dx.doi.org/10.1016/j.ress.2021.107881

European Commission, D.-G. f. E., Regulatory priorities for enabling demand side flexibility. 2020

Alam, M. S.; Al-Ismail, F. S.; Salem, A.; Abido, M. A., High-Level Penetration of Renewable Energy Sources Into Grid Utility: Challenges and Solutions. *IEEE Access* 2020, 8, 190277-190299. http://dx.doi.org/10.1109/access.2020.3031481

Qayyum, F. A.; Naeem, M.; Khwaja, A. S.; Anpalagan, A.; Guan, L.; Venkatesh, B., Appliance Scheduling Optimization in Smart Home Networks. *IEEE Access* 2015, 3, 2176-2190. http://dx.doi.org/10.1109/access.2015.2496117

6TH INTERNATIONAL CONFERENCE ENRE - ENERGY & RESPONSIBILITY
BOOK OF EXTENDED ABSTRACTS
S. Seme, K. Sredenšek (eds.)
University of Maribor Press

THE IMPACT OF GEOPOLITICAL FACTORS AND FINANCIAL SUPPORT MECHANISMS ON THE PROFITABILITY OF INVESTMENTS IN SOLAR POWER PLANTS IN SLOVENIA

IZTOK GORNJAK,[1] NIKO SAMEC[2]

[1] Borzen, d.o.o., Ljubljana, Slovenia
iztok.gornjak@borzen.si
[2] University of Maribor, Faculty of Mechanical Engineering, Maribor, Slovenia
niko.samec@um.si

Keywords: renewable energy sources; solar power plants; support system; investment profitability factors; geopolitical factors

The energy policy of the European Union places special emphasis on increasing the share of renewable energy sources, leading to a reduction in dependence on unreliable and volatile fossil fuel markets. Solar power plants play a crucial role in this transition. The energy policy also includes mechanisms or support systems for the operation of such facilities and devices. The article provides an analysis of the movement of electricity prices in the last decade, and answers the question of which type of support (guaranteed purchase or operational support) has proven to be more profitable for investments in solar power plants up to 50 kW in Slovenia in the last decade, considering the impact of economic and geopolitical factors on the electricity market. Although the world has witnessed numerous global events in the past years affecting energy markets, it has been shown that the COVID-19 pandemic has not impacted the electricity market significantly. In contrast to the pandemic, the start of the war in Ukraine affected not only the rise in electricity prices, but also changes in the dynamics of supports that are crucial for the development and sustainability of renewable energy systems. Analyses of the past decade show primarily a

higher profitability of investment in solar power plants, by choosing the operational support mechanism over guaranteed purchase support.

6TH INTERNATIONAL CONFERENCE ENRE - ENERGY & RESPONSIBILITY
BOOK OF EXTENDED ABSTRACTS
S. Seme, K. Sredenšek (eds.)
University of Maribor Press

STRATEGIC OPTIMISATION OF BATTERY STORAGE SIZE AND LOCATION FOR ENHANCED VOLTAGE PROFILES IN DISTRIBUTION NETWORKS

MILOŠ BEKOVIĆ,[1] MIRAN HORVAT,[2] MATEJ PINTARIČ,[1]
DARIJAN STIPANOVIĆ[1]

[1] University of Maribor, Faculty of Electrical Engineering and Computer Science, Maribor, Slovenia
milos.bekovic@um.si, darijan.stipanovic@student.um.si, matej.pintaric1@um.si
[2] Elektro Maribor, d.d., Vetrinjska ulica 2, Maribor, Slovenia
miran.horvat@elektro-maribor.si

Keywords: BESS, load-flow, distribution network, voltage profile, optimisation

The green transition and corresponding policies within the European Union have spurred the integration of distributed renewable energy sources (RES). Primarily consisting of small to medium-sized solar power plants, these installations are typically linked to the grid within the low-voltage (LV) segment of the distribution network (DN).

The focus of this article is determining the optimal size and location of Battery Energy Storage Systems (BESS), to enhance the voltage profile within the LV segment of the DN. Our approach assumes that the ideal location for the BESS is at a node within one LV outlet, requiring minimal BESS power to uphold voltage profiles within predetermined limits across all nodes within that outlet. Additionally, we base our algorithm design on this assumption, to facilitate the selection of the optimal BESS size and location.

The primary motivation behind this paper is to address challenges encountered by local DSOs from the perspective of a network planner. Daily, network planners grapple with issues surrounding inadequate voltage profiles, a problem that can be addressed effectively

through the methods proposed herein. This topic holds significant relevance, as the problem remains a key barrier to the seamless integration of renewable resources into the network infrastructure.

The article will cover the following key topics:

- Development of an algorithm to determine the optimal size and location of a BESS for resolving voltage profile issues within a single LV source.
- Evaluation of the BESS technologies to ascertain the most suitable option, followed by the sizing of the chosen technology.
- Simulation-based verification of the BESS's ability to influence the voltage profile. This will involve scenarios where the BESS is discharged or charged as required by network demands, validated through simulations conducted on the selected network configuration.

The presented paper will be constrained by the following limitations:

- Limited availability of load measurements and voltage profiles within the DN
- The necessity to account for the asymmetric load of the lines during the modelling and simulation of the LV network, based on the available measured variables.
- Measurement data spanning only fourteen days, acquired on-site, imposing a temporal constraint on the analysis.
- Due to the restricted timeframe of measurements, the determination of the optimal location and size of the BESS can only be conducted for the specified period.

References

Boonluk P., Siritaratiwat A., Fuangfoo P., Khunkitti, S. Optimal Siting and Sizing of Battery Energy Storage Systems for Distribution Network of Distribution System Operators. Batteries, Volume 6, Number 56, 2020. Dostopno na: https://doi.org/10.3390/batteries6040056

6TH INTERNATIONAL CONFERENCE ENRE - ENERGY & RESPONSIBILITY
BOOK OF EXTENDED ABSTRACTS
S. Seme, K. Sredenšek (eds.)
University of Maribor Press

3DIVERSE – NOVEL APPROACHES TO TANGIBLE ENERGY TRANSITION WITH DIVERSIFICATION OF PRODUCTION SOURCES IN DISTRICT HEATING AND LOCALIZED GENERATION OF ELECTRICITY

BOŠTJAN KRAJNC, NIKO NATEK, NEJC JURKO
Energy Agency of Savinjska, Šaleška and Koroška region, Velenje, Slovenia
Bostjan.krajnc@kssena.velenje.eu, niko.natek@kssena.velenje.eu; nejc.jurko@kssena.velenje.eu

Keywords: investments in sustainable energy infrastructure, deep energy renovation, renewable electricity generation, renewables energy storage, energy efficiency

3DIVERSE implements a holistic, multi-sectoral and multi-level approach to planning and implementing investments in sustainable energy infrastructure through the coordinated application of supply and demand side measures. The conventional fragmented and piecemeal approach to investments, which are collectively essential for the successful implementation of the energy transition, will be replaced by a novel approach based on the integration and aggregation of investments in four interconnected sectors, which will ensure optimal results in terms of environmental, socio-economic and financial benefits. The project will address four sectors critical to the energy transition collectively:

- A sustainable and low-carbon energy supply for space heating and domestic hot water (decarbonization through comprehensive renovation of the local district heating system by phasing out fossil fuels, substitution with renewable energy sources and improved process control).

- Deep energy renovation of existing buildings (implementing comprehensive energy renovation measures to reduce final energy demand and supporting renovation approaches based on decentralized energy production - consumers become prosumers, investors and beneficiaries).
- Renewable electricity generation, storage and load management (facilitating investment in renewable energy capacity and developing capacity for load management and grid stability).
- Zero emission mobility with alternative propulsion (improved access to public transport and access to a sustainable transport infrastructure based on zero emission technologies).

The 3DIVERSE approach is based on the premise of maximizing the mobilization of private capital, and encouraging community-driven investment by providing mechanisms that ensure better access to capital, lower investment costs, high transparency and financial and social incentives.

References

Gregor Cvet (2016), Daljinsko ogrevanje v Šaleški dolini nekoč in danes. Technical report, Komunalno podjetje Velenje, d.o.o.

Tomaž Kužner (2022), Zelena transofrmacija KPV. Predstavitev KPV

Elektro Celje, EU projekt 3DIVERSE - podatki, Ljubljana, 2023

Mestna Občina Velenje, Lokalni Energetski koncept, Velenje, 2022

Mestna Občina Šoštanj, Lokalni Energetski Koncept, Šoštanj, 2022

Mestna Obična Šmartno ob Paki, Lokalni Energetski Koncept, Šmartno ob Paki

Solar Smiths, [Elektronski]. Available: https://www.solarsmiths.com/blog/solar-rooftop-system-technical-faqs/. [Poskus dostopa 31 marec 2023]

TEŠ, [Elektronski]. Available: https://www.te-sostanj.si/aktualno/medijsko-sredisce/letna-porocila/. [Poskus dostopa 17 marec 2023]

Our World in Data, [Elektronski]. Available: https://ourworldindata.org/co2/country/slovenia. [Poskus dostopa 17 marec 2023]

Municipality of Velenje, Sustainable energy transition,Velenje

Fuel cells and hydrogen, joint undetaking, [Elektronski]. Available: http://www.fch.europa.eu/project/clean-hydrogen-european-cities . [Poskus dostopa 20 marec 2023]

Plug, [Elektronski]. Available: https://resources.plugpower.com/electrolyzers/ex-425d-f041122. [Poskus dostopa 24 marec 2023]

6TH INTERNATIONAL CONFERENCE ENRE - ENERGY & RESPONSIBILITY
BOOK OF EXTENDED ABSTRACTS
S. Seme, K. Sredenšek (eds.)

University of Maribor Press

EVALUATION OF ENERGY FLOWS IN THE DISCTRICT HEATING SYSTEM IN VELENJE

MARKO KEBER,[1] TINE SELJAK,[1] KATJA KLINAR,[1] ANDREJ KITANOVSKI,[1] JANEZ RAMŠAK[2]

University of Ljubljana, Faculty of Mechanical Engineering, Ljubljana, Slovenia
marko.keber@fs.uni-lj.si, tine.seljak@fs.uni-lj.si, katja.klinar@fs.uni-lj.si, andrej.kitanovski@fs.uni-lj.si
Komunalno podjetje Velenje, d.o.o., Velenje, Slovenia
janez.ramsak@kp-velenje.si

Keywords: district heating system modelling, heat flow losses, reduction of CO_2 emissions, pipeline insulation, lowering temperature regimes

Considerable improvements in the efficiency of an existing district heating system can be achieved by upgrading the thermal performance of its distribution, which, in a large and complex network such as the one in Velenje, has a sizable impact on the overall energy consumption required for heating, and, consequently, also on the amount of local CO2 emissions. These can be greatly reduced by replacing the damaged pipeline insulation material and by lowering the temperature regimes. Simulations carried out with a reduced-order model developed by Keber et al. (2023), which is based on the steady-state condition of the system and the simplified form of the conservation of energy (Duquette et al., 2016), indicate that insulation has a much more pronounced effect on total system losses compared to the changed temperature regime. In the given example, where certain sections in the original pipeline configuration are insulated insufficiently, lowering supply temperatures by about 15% without introducing other improvements will reduce heat flow losses by a similar amount, between 15% and 20%. With the addition of new insulation, the losses can be reduced in some cases by more than 80%. Applying the same lower temperature regime on the fully insulated system will provide further savings, albeit at a more modest rate. Although more savings could be obtained with lowering of the system's temperatures below 100°C, the study was limited to examples where, according to

Bolonina et al. (2015), major modifications of the district heating network would not be expected.

References

Duquette, J., Rowe, A., Wild, P (2016). Thermal performance of a steady state physical pipe model for simulating district heating grids with variable flow. *Applied Energy, 178*, 383-393. doi: 10.1016/j.apenergy.2016.06.092

Keber, M., Kitanovski, A., Seljak, T. (2023). A data-driven reduced-order model for evaluating energy flows in a topologically complex district heating system. *Svet strojništva, 12*, 154-155. doi:10.62020/svet.str.as20230154

Bolonina, A., Bolonins, G., Blumberga, D. (2015). Analysis of the impact of decreasing district heating supply temperature on combined heat and power plant operation. *Environmental and Climate Technologies*, *14(1)*, 41-46. doi: 10.1515/rtuect-2014-0013

<EnRe>
energy & responsibility

HYDROPOWER, THERMAL POWER, AND NUCLEAR POWER

6TH INTERNATIONAL CONFERENCE ENRE - ENERGY & RESPONSIBILITY
BOOK OF EXTENDED ABSTRACTS
S. Seme, K. Sredenšek (eds.)

University of Maribor Press

ENERGY RENOVATION OF MULTI-APARTMENT BUILDINGS AS A POTENTIAL FOR LOWERING THE TEMPERATURE REGIME OF THE ŠALEŠKA VALLEY DISTRICT HEATING

GREGOR CVET
Komunalno podjetje Velenje, Velenje, Slovenia
gregor.cvet@kp-velenje.si

Keywords: operation optimization, district heating, multi-apartment buildings, temperature regimes, heat loss

The utility company Velenje, as a heat energy distributor, is facing a big challenge, as it is in the phase of transformation of the Šaleška Valley district heating system. One of the main tasks of the transformation is the transition to a lower operating temperature regime of the entire heat distribution system.

The article analyzes the approach to lowering the entire temperature regime of the district heating of the Šaleška Valley on the basis of implemented and planned energy renovations of the thermal envelope of multi-apartment buildings in the area of the Municipality of Velenje (MOV). The starting points are presented for changing the existing temperature diagrams of the distribution network and the effects of the transition of energy-renovated buildings from the existing high temperature regime of 85/65°C to the reduced temperature regime of 70/50°C. Test measurements of the internal heating installations of energy-renovated buildings show that living spaces can be heated in the winter months with a temperature in the range between 40-55°C.

The general conclusion of the article is that the transition of buildings to a lower heating temperature regime represents a great potential to lower the temperature regime of the main, primary and secondary networks, and, consequently, to lower the heat losses of the entire heat distribution system of the Šaleška Valley. Lower temperature heating paves the way for the integration of renewable production heat sources and the decarbonization of the existing high temperature heating method.

6TH INTERNATIONAL CONFERENCE ENRE - ENERGY & RESPONSIBILITY
BOOK OF EXTENDED ABSTRACTS
S. Seme, K. Sredenšek (eds.)

University of Maribor Press

PIV MEASUREMENTS OF WATER FLOW DURING ULTRASONIC ATOMIZATION

MATEJ FIKE, ANDREJ PREDIN, ANDRAŽ ROGER
University of Maribor, Faculty of Energy Technology, Krško, Slovenia
matej.fike@um.si, andrej.predin@um.si, andraz.roger@um.si

Keywords: PIV, vector field, cavitation, laser, capillary waves theory, ultrasonic transducer

This study investigates the ultrasonic atomization of water using a piezoelectric transducer, employing a 2D Particle Image Velocimetry (PIV) system to track 50 μm polyamide particles, revealing particle movement vectors near the transducer. The PIV system facilitates analysis of water current movements, enhancing understanding of ultrasonic atomization dynamics. Observations include fluid flow from the sonotrode to the surface, implying the effects of ultrasonic waves on liquid dynamics and cavitation bubble interaction with capillary waves. An Nd:YAG laser from Litron Lasers, equipped with a 532 nm harmonizer and polarization attenuator, illuminated the scene, with Dantec Dynamics providing the optics, camera, and analysis software. The water was seeded with polyamide powder to visualize particle movements. Utilizing "double frame" capture, 60 images at 100 Hz were acquired, calculating velocity vectors to demonstrate the consistent direction and speed above the transducer.

The results assemble a vector field above the nultrasonic transducer at a specific time. The water flows from the sensor to the surface, and the velocity near the sensor is lower than near the surface, which may indicate the fact that cavitation bubbles travel from the ceramic plate of the ultrasonic actuator towards the surface.

References

Deepu, P., Peng, C., & Moghaddam, S. (2018). Dynamics of ultrasonic atomization of droplets. *Experimental Thermal and Fluid Science*, *92*, 243-247. https://doi.org/https://doi.org/10.1016/j.expthermflusci.2017.11.021

Priyadarshi, A., Bin Shahrani, S., Choma, T., Zrodowski, L., Qin, L., Leung, C. L. A., Clark, S. J., Fezzaa, K., Mi, J., Lee, P. D., Eskin, D., & Tzanakis, I. (2024). New insights into the mechanism of ultrasonic atomization for the production of metal powders in additive manufacturing. *Additive Manufacturing*, *83*, 104033. https://doi.org/https://doi.org/10.1016/j.addma.2024.104033

6TH INTERNATIONAL CONFERENCE ENRE - ENERGY & RESPONSIBILITY
BOOK OF EXTENDED ABSTRACTS
S. Seme, K. Sredenšek (eds.)

University of Maribor Press

CONSERVATION OF FISH MIGRATIONS AT HYDROELECTRIC POWER PLANTS: FISH PASSAGE SYSTEMS AS AN ENVIRONMENTALLY RESPONSIBLE MEASURE

SANDRA VELKOVSKI, BOŠTJAN PIŠOTEK
Hidroelektrarne na Spodnji Savi, d.o.o., Brežice, Slovenia
sandra.velkovski@he-ss.si, bostjan.pisotek@he-ss.si

Keywords: energy-environmental synergy, environmental protection, fish crossings, hydropower, multipurpose projects, self-sufficiency

The geostrategic situation in the world reminds us that, for a country that wants to be sovereign, it is necessary to strengthen the degree of self-sufficiency in energy and food production as soon as possible, while, at the same time, taking care of sustainable environmental and social development. In the field of Renewable Energy Sources, Slovenia has the greatest privilege in the use of hydropower and wood biomass. The paper presents the importance of implementing multi-purpose and goal-oriented projects, such as hydroelectric power plants (HPP), which fulfil several set strategies of the State and local communities. Since every human intervention in the environment has certain impacts, the paper shows how synergistic effects can be created between environmental protection and energy development through responsible environmental planning and implementation of the best possible measures on a practical example of the multi-purpose construction project of an HPP on the lower Sava. Specifically, the multi-year results are presented of the fish passage at the HPP Arto-Blanca. These are so-called mitigation measures that allow fish species to migrate past hydroelectric power plants and thus maintain healthy fish populations; maintain genetic diversity; connect and preserve the

entire aquatic ecosystem. The paper introduces the topic of fish migrations and barriers on watercourses in the introduction, and shows the current situation in Slovenia and around the world. In the core, an example of the effectiveness of the operation of the fish passage at HPP Arto-Blanca is discussed, which is supported by concrete data from multi-year monitoring. The trend and obligations in planning such passages in the future are presented using the example of future HPPs in Slovenia. In the synthesis, a discussion is held on the improvement or symbiosis of energy and the environment over time.

References

Pišotek, B. (2023). Green capital for environmental development. *Information Society, Proceedings of the 26th International Multiconference, Volume D*, 19-26. IS2023_Volume-D.pdf (ijs.si)

6TH INTERNATIONAL CONFERENCE EnRe - ENERGY & RESPONSIBILITY
BOOK OF EXTENDED ABSTRACTS
S. Seme, K. Sredenšek (eds.)
University of Maribor Press

ENVIRONMENTAL AND ECONOMIC PERFORMANCE OF EU CRITICAL MATERIAL RECYCLING FROM A PROTON EXCHANGE MEMBRANE FUEL CELL

ROK STROPNIK,[1] JURE GRAMC,[1] MIHAEL SEKAVČNIK,[1] ANNA MARCHISIO,[2] ORHUN DEDECI,[3] MITJA MORI[1]

[1] University of Ljubljana, Faculty of Mechanical Engineering, Ljubljana, Slovenia
rok.stropnik@fs.uni-lj.si, mitja.mori@fs.uni-lj.si, jure.gramc@fs.uni-lj.si, mihael.sekavcnik@fs.uni-lj.si
[2] Hensel Recycling, Aschaffenburg, Germany
a.marchisio@hensel-recycling.com
[3] IDO-Lab, Karlstein, Germany
o.dedeci@ido-lab.com

Keywords: sustainability, environmental life cycle assessment (E-LCA), life cycle cost (LCC), Proton exchange membrane fuel cell (PEMFC), circular economy, recycling

The EU has set itself the ambitious goal of reducing its impact on the environment while ensuring economic and social sustainability. The EU's concern about climate change and depletion of natural resources has sparked interest in fuel cell and hydrogen (FCH) technologies, along with the search for sustainable ways to produce, transport and use hydrogen (Clean Hydrogen Joint Undertaking, 2022). One of the key points to pursue these sustainable pathways is the proper consideration of critical EU materials, which are becoming increasingly important for FCH technologies from an economic and environmental perspective. The EU's focus is on the recovery of critical materials in all future technologies where platinum is a particular focus, especially in PEMFC technology. The work carried out as part of the EU-funded BEST4Hy project aimed to produce innovative life-cycle inventories of recycling technologies, and to assess the environmental and economic life-cycle performance of PEMFC recycling processes. In this work, the

hydrometallurgical process for the recovery of platinum from the waste PEMFC stack in the form of Pt salt for closed-loop recycling is presented in detail. An LCA methodology was used to calculate the environmental impact of Pt recycling, and a new life-cycle cost (LCC) model was developed for the economic performance. The environmental impact results show that recovered Pt has a significantly lower impact (82%) compared to virgin Pt. This means that this recycling technology shows promising results in the context of the circular economy, and the LCC also shows promising economic potential for the recycling industry.

References

Clean Hydrogen Joint Undertaking (2022). Clean hydrogen joint undertaking: strategic research and innovation agenda 2021-2027, 10.13140/2.1.4252.7520

Stropnik Rok, Mori Mitja, Gramc Jure (2024). Sustainable SoluTions FOR recycling of end-of-life Hydrogen technologies (BEST4Hy); Deliverable D5.2 LCA and LCC impacts of novel EoL technologies and ecolabelling of FCH products.

SustainaBlE SoluTions FOR recycling of end-of-life Hydrogen technologies (BEST4Hy) (2021) H2020, CORDIS, European Commission; https://cordis.europa.eu/project/id/101007216.

6TH INTERNATIONAL CONFERENCE ENRE - ENERGY & RESPONSIBILITY
BOOK OF EXTENDED ABSTRACTS
S. Seme, K. Sredenšek (eds.)
University of Maribor Press

SPENT NUCLEAR FUEL CHARACTERIZATION

MARJAN KROMAR,[1, 2] DUŠAN ČALIČ[1, 2]
[1] Jožef Stefan Institute, Reactor Physics Department, Ljubljana, Slovenia
marjan.kromar@ijs.si, dusan.calic@ijs.si
[2] University of Maribor, Faculty of Energy Technology, Krško, Slovenia
marjan.kromar@um.si, dusan.calic@um.si

Keywords: spent nuclear fuel, decay heat, activity, neutron emission, photon emission

Accurate determination of the spent nuclear fuel characteristics, such as decay heat, activity, neutron and photon source term, is essential for the safe and economically efficient Spent Fuel (SF) storage, transport and disposal. Some of the observables can be determined using non-destructive analysis methods. However, due to the considerable time required for such measurements, it is impractical to measure every single spent fuel assembly. Rather, one should rely on the prediction capabilities through modeling and simulations, coupled with a limited number of validation measurements. The importance of adequate calculations, with a reliable estimation of uncertainties and biases, is, therefore, of paramount importance (Rochman, Kromar, et al., 2023).

Spent fuel characterization calculation uncertainties are coming from:

- Calculation methods (stochastic or deterministic)
- Nuclear data
- Modeling approximations

For a solid characterization process, calculation methods should be validated thoroughly against the benchmark experiments. The accuracy of the nuclear data libraries has been improving over time. Nevertheless, the uncertainty associated with the applied library

should be determined for the particular application (Čalič, Kromar, 2022). Modeling uncertainties are caused by:

- Lack of the precise SF irradiation history data
- Uncertainties in the as-built manufacturing SF data
- Approximate nature of the calculation models

A comparison of the predictions with the benchmark measurements seems to indicate that, with the current state-of-the-art methods and models, decay heat prediction cannot be expected to be better than 5% (one Standard Deviation) (Rochman, Kromar, et al., 2023). The uncertainties in the neutron and photon emission rate are, due to the specific nature of both observables, higher.

References

Rochman, D. A., Kromar, M., et al. (2023). On the estimation of nuclide inventory and decay heat: a review from the EURAD European project, *EPJ Nuclear Sci. Technol.,* 9, https://doi.org/10.1051/epjn/2022055

Čalič, D., Kromar, M., (2022). Spent fuel characterization analysis using various nuclear data libraries, *Nuclear Engineering and Technology, 54*, 3260-3271, DOI: 10.1016/j.net.2022.04.009.

6TH INTERNATIONAL CONFERENCE ENRE - ENERGY & RESPONSIBILITY
BOOK OF EXTENDED ABSTRACTS
S. Seme, K. Sredenšek (eds.)

University of Maribor Press

FAILURE ANALYSIS OF THE BRASS COOLING TUBES IN A STEAM TURBINE CONDENSER

DUŠAN STRUŠNIK, JURIJ AVSEC
University of Maribor, Faculty of Energy Technology, Krško, Slovenia
dusan.strusnik1@guest.um.si, jurij.avsec@um.si

Keywords: analaysis, ammonian, cooling, cracks, tubes

The STC (steam turbine condenser) is a surface, shell and tube type vacuum condenser, cooled by a cooling water system from a river. The STC has two water passes and two water flows. The condenser shell is made of carbon steel, and has 4,910 cooling tubes made from CuZn28Sn1As brass (dimensions 23,0 x 1,0 mm, 6.400 mm length).

Three new steam dump devices (SDDs) were added onto the condenser. Two SDDs are used for high-pressure (HP) steam and one is used for low-pressure (LP) steam.

The basic purpose of the SDDs is to dump steam from the boiler, via the bypass system, into the STC. The bypass system is used mainly during start-ups, shutdowns and the transfer of excess steam.

The Commissioning and Trials Board tested the new SDDs. The trials ran for five hours. During commissioning high condensate levels in STC have caused trips. In addition, online monitoring showed high conductance of condensate. After opening the condenser water chamber doors, and filling the steam side of the condenser with water, it was observed that twenty-eight cooling tubes were leaking. The leaking tubes were plugged. Four cooling tubes were extracted and two condensate samples were provided for analysis. During the extraction of the cooling tubes the other tubes were checked visually with a borescope, to determine the internal condition of the tubes.

The analysis results show that all cracks on the tubes that were extracted are at the same position on the tubes, about 5 mm from the tube sheet on the front side of the condenser, where the cooling water inlet and outlet are located. Grooves were found on all the other tubes at the same place, and are characteristic of stress-corrosion cracking influenced by ammonia.

References

Donald D. Van Slyke. The Analysis of Proteins by Determination of the Chemical Groups Characteristic of the Different Amino-Acids. *A journal of the American Society for Biochemistry and Molecular Biology*, Pages 15-55. https://doi.org/10.1016/S0021-9258(18)91437-7.

T.S Rao, K.V.K Nair (1998). Microbiologically influenced stress corrosion cracking failure of admiralty brass condenser tubes in a nuclear power plant cooled by freshwater. *Corrosion Science,* 40, Issue, 1821-1836 https://doi.org/10.1016/S0010-938X(98)00079-1.

Emad Sharifi, Khalil Ranjbar (2022). Dezincification assisted cracking of yellow brass tubes in a heat exchanger. *Engineering Failure Analysis,* 136, 2022, 106200 https://doi.org/10.1016/j.engfailanal.2022.106200.

Yong-De Li, Na Xu, Xiao-Feng Wu, Wei-Min Guo, Jun-Bo Shi, Qi-Shan Zang (2013) Failure analysis of the condenser brass tube in 150 MW thermal power units. Engineering *Failure Analysis*, 33, 75-82 https://doi.org/10.1016/j.engfailanal.2013.04.026.

6TH INTERNATIONAL CONFERENCE EnRe - ENERGY & RESPONSIBILITY
BOOK OF EXTENDED ABSTRACTS
S. Seme, K. Sredenšek (eds.)

University of Maribor Press

ANALYSIS OF THE ELECTRICITY, HEAT AND CARBON FOOTPRINT OF AN EDUCATIONAL ESTABLISHMENT

DRAGO PAPLER, MARIJAN POGAČNIK
Biotehnical Centre Naklo, Naklo, Slovenia
drago.papler@bc-naklo.si, marijan.pogacnik@bc-naklo.si

Keywords: electricity, heat, consumption, generation, self-supply, energy efficiency, renewables, impact analysis, carbon footprint, climate change

The electricity supply at Naklo Biotechnical Centre increased by 12.09% to 574,677 kWh in the period 2017-2023. During the COVID-19 pandemic, the total consumption decreased by 30.64% in 2021. The solar power plant, with a rated capacity of 89.835 kW, which is connected to the internal grid, supplied 82.368 kWh of electricity in the bad weather year 2023, or 15.36% of the total demand; and 101.258 kWh of electricity in the good weather year 2022, or 25.72% of the total demand. The remaining electricity was supplied by ECE, Ltd., ranging from 74.28% in 2022 to 85.67% in 2023. The electricity consumed ranged from 56.1% to 58.6% during the higher daily tariff when the educational process is taking place, and from 41.4% to 43.9% during the lower tariff when sporting activities and commercial and extra-curricular activities are taking place. Heating with extra-light fuel oil has been replaced gradually by the new energy source, natural gas. During the COVID-19 pandemic in 2020, heat consumption was reduced by 16.2%.

For heating, natural gas accounted for 97% of the consumption in 2023, with 1,129,866 kWh. The greenhouses are heated with fuel oil, and the dairy and fruit workshop with wood chips. The carbon footprint of the heat consumed has been reduced by 20.9% from 2,753.88 tonnes of CO2 emissions to 2,178.25 tonnes of CO2 emissions by replacing fuel

oil with natural gas. The total carbon footprint of electricity and heat was reduced by 18.6%, from 3,185.05 t of CO2 emissions to 2,592.28 t of CO2 emissions.

6TH INTERNATIONAL CONFERENCE ENRE - ENERGY & RESPONSIBILITY
BOOK OF EXTENDED ABSTRACTS
S. Seme, K. Sredenšek (eds.)
University of Maribor Press

HYBRID ENERGY STORAGE SYSTEM USING A POST-MINING INFRASTRUCTURE (HESS)

SERGEJ JAMNIKAR, JANEZ ROŠER
Premogovnik Velenje, d.o.o., Velenje, Slovenija
sergej.jamnikar@rlv.si, janez.roser@rlv.si

Keywords: hybrid energy storage, post-mining infrastructure, abandoned shafts, electrical energy, thermal energy, energy exchange

The HESS Project is an international research project, funded by the Research Fund for Coal and Steel, with the major aim to develop a hybrid energy storage system by using the post-mining infrastructure that include shafts and other underground spaces. The partnership of universities, institutes and industry investigates the possibility of its use for parallel energy storage in pumped storage systems, compressed gas – air and CO2 systems, and thermal energy storage. The potentials of geothermal energy and CO2 storage will also be investigated additionally.

The assumed total energy storage capacity will be 30 MW. Each HESS component will have its own thermal and mechanical integration algorithm, which will be developed during the project. Optimal cooperation of HESS's various elements will be supervised by an energy router, which will manage energy exchanges with the national power grid for the intake of low-cost green energy and peak energy production.

Technical and economic analysis will form the basis for work on the construction of a pilot plant and industrial implementation of the project results, which is believed to offer many technological, economic and environment-friendly transition solutions for existing coal regions.

Premogovnik Velenje (Coal Mine Velenje) is a Slovene partner in the project, and provides technical data for system modelling and accesses feasible solutions.

The HESS project is funded by the Research Fund for Coal and Steel, and includes the Institute of Energy and Fuel Processing Technology (Poland), the Silesian University of Technology (Poland), Institut Techniki Gorniczej (Poland), the Technical University of Ostrava (Czech Republic), and Premogovnik Velenje (Slovenia).

6TH INTERNATIONAL CONFERENCE ENRE - ENERGY & RESPONSIBILITY
BOOK OF EXTENDED ABSTRACTS
S. Seme, K. Sredenšek (eds.)

University of Maribor Press

ASSESSING THE INFLUENCE OF HYDROELECTRIC POWER PLANTS ON FISH SPAWNING HABITATS

MARKO PEZDEVŠEK, ANDREJ PREDIN, MATEJ FIKE, ANDRAŽ ROGER, GORAZD HREN

University of Maribor, Faculty of Energy Technology, Krško, Slovenia
marko.pezdevsek@um.si, andrej.predin@um.si, matej.fike@um.si, andraz.roger@um.si, gorazd.hren@um.si

Keywords: hydroelectric power plant, fish, spawning, habitat, environmental impact

This paper discusses the impact of man-made hydraulic river structures, particularly hydroelectric power plants, on river ecosystems. These structures, while serving purposes like flood management and energy production, disrupt natural flows and habitats. The construction of multiple hydroelectric power plants along a river can lead to alterations in flow patterns and depths, affecting upstream tributaries. Concerns raised by non-governmental organisations highlight the threat to various fish species protected under EU Directives, especially at critical spawning grounds.

Studies commissioned by environmental groups emphasise the significance of disputes surrounding specific hydroelectric power plant projects in shaping the future of the ecosystem and the survival of species. The change in water levels caused by hydroelectric power plants impacts rivers significantly and, consequently, fish spawning habitats. The proposed sustainable measures aim to mitigate these impacts by simulating flood levels and focusing on preserving spawning areas for representative fish species.

The implementation of such measures, including lifting the river bottom and creating pebble habitats, is crucial for maintaining hydrological and ecological balance. Without these interventions, there is a risk of further degradation of river ecosystems and loss of fish habitats. However, the current focus on spawning and river hydraulics neglects the broader needs of fish populations at different life stages. Future investigations should prioritise understanding the habitat requirements of all endangered species, and implementing measures to enhance habitat quality throughout the river system.

6TH INTERNATIONAL CONFERENCE ENRE - ENERGY & RESPONSIBILITY
BOOK OF EXTENDED ABSTRACTS
S. Seme, K. Sredenšek (eds.)
University of Maribor Press

DESIGN AND CREATION OF A VIRTUAL MODEL OF LOW-CARBON ENERGY RESOURCES

GORAZD HREN,[1] ANDREJ PREDIN,[1] BOŠTJAN PIŠOTEK,[2] GARSIA KOSINC,[3] MARKO PEZDEVŠEK[1]

[1] University of Maribor, Faculty of Energy Technology, Krško, Slovenia
gorazd.hren@um.si, andrej.predin@um.si, marko.pezdevsek@um.si
[2] HESS, Hidroelektrarne na spodnji Savi, Brežice, Slovenia
bostjan.pisotek@he-ss.si
[3] GEN energija, Vrbina, Slovenia
garsia.kosinac@gen-energija.si

Keywords: virtual model, mockup, mapping, 3D print, low-carbon energy

On the order of xx, we created and produced a virtual model of low-carbon energy sources. The model includes a computer visualization of individual objects arranged in a common disposition of placement. The layout is arranged in two levels, one represents the new block of the nuclear power plant in Vrbina with a silo for the storage of low-level radioactive waste, and the other the HPP Mokrice, with its surroundings and the construction of fishing lanes. From HESS and IBE, we obtained basic models for the hydroelectric power plant and its surroundings, as well as a silo for the storage of low-level radioactive waste. There are still no basic data on the second nuclear power plant unit, so the second nuclear power plant unit is a transferred generic model. The disposition also includes a silo for storing low-level radioactive waste, and the basic model is also provided by IBE. The basic layout is arranged in the form of a mock-up and ready for 3D printing, as shown in the picture. All the models were transferred using standard interfaces (STEP, IGES) and mapped and placed in space. Mapping includes, firstly, reduction to suitable dimensions, subsequent deletion of details that are too small for 3D printing, and assembly of individual models into a solid model as preparation of the model for 3D printing. Preparation for 3D printing includes cutting models according to the dimensions

of the 3D printers, constructing connection points, and, of course, supports. After printing, the models were cleaned, sanded, assembled, and painted.

6TH INTERNATIONAL CONFERENCE ENRE - ENERGY & RESPONSIBILITY
BOOK OF EXTENDED ABSTRACTS
S. Seme, K. Sredenšek (eds.)

University of Maribor Press

THE PROCESS OF DEMOCRATIC DECISION-MAKING ON THE SLOVENIAN NUCLEAR FUTURE

ČRT POGLAJEN
University of Ljubljana, Faculty for Social Sciences, Ljubljana, Slovenia
poglajen.crt@gmail.com, crt.poglajen@gov

Keywords: deliberative process, Referendum on the Slovenian energy future, Three dimensions of the Slovenian Energy System, Paris Agreement, European Green Deal, Aarhus Convention

The main topic I am going to focus on in my presentation is a crucial strategic decision Slovenia is faced with at the level of its energy future. It has to decide whether the new nuclear power plant in Krško is going to be built or not.

At the beginning of 2024 the Prime Minister, President of the Republic of Slovenia, President of the National Assembly, President of the National Council and Presidents of parliamentary parties all agreed that the Referendum on theSlovenian Nuclear future was going to be held in November 2024. To secure the expert support people need to make an educated decision in such a complex matter the Slovenian government decided to fallow the experience of the most developed democratic systems in Europe and the World. In cooperation with colleagues from Holland, Denmark and Sweeden, where they are using deliberation processes to secure energy transition, Slovenia will use a deliberative assembly to include its citizens in scientific, reasonable and non-populistic discourse.

I am going to focus on three fundamental strategical questions: Why is the deliberation as a process so important for the legitimacy of the current Referendum on the nuclear power plant? Why is the deliberation process as a basic democratic form so important for

Slovenian energy transition, and why we have to change all three key dimensions of the Slovenian Energy System to secure the synchronization of its development with key elements of the Paris Agreement, European Green Deal and Aarhus Convention?

References

Eckersly, R. (2004) The Green State: Rethinking Democracy and Sovereignty, The MIT Press.
Hajer, Maarten A. (2002) The Politics of Environmental Discourse Ecological Modernization and the Policy Process, Clarendon Press, Oxford.
Hughes, B. B., Rycroft, R., Sylvan, D., Trout, B. in Harf, J. (1985) Energy in the global arena, Duke University Press.
Klopčič, A.L., Hojnik, J. in Pustovrh, A. (2022/3) ACER's Success in Establishing and Ensuring the Functioning of the Internal Energy Market: Through the Eyes of Traders, Managing Global Transitions 18 (2): 91–110.
Macperson, C. B. (1973) Democratic Theory: Essays in Retrieval, Claredon Press.
Monstadt J. in Wolff A. (2015) Energy transition or incremental change? Green policy agendas and the adaptability of the urban energy regime in Los Angeles, Energy Policy, Volume 78, March 2015, Pages 213-224
O'Halloran, K. (2022) Critical discourse analysis and language cognition, Critical Discourse Analysis and Language Cognition, Edinburgh University Press
Poglajen, Č. (2024) Politološka analiza trajnostnosti v slovenski elektroenergetski areni, Fakulteta za družbene vede, Univerza v Ljubljani
Tkalec, T. (2016) Politološki aspekti decentralizacije proizvodnje električne energije, doktorska disertacija, Fakulteta za družbene vede, Univerza v Ljubljani
Verba, S., Schlozman, K. L., Brady, H., & Nie, N. H. (1993) Citizen activity: Who participates? What do they say, American Political Science Review, 87(2), 303-318
Wu, X., Tian, Z. in Guo, J. (2022) A review of the theoretical research and practical progress of carbon neutrality, Sustainable Operations and Computers, 3, 54-66

6TH INTERNATIONAL CONFERENCE ENRE - ENERGY & RESPONSIBILITY
BOOK OF EXTENDED ABSTRACTS
S. Seme, K. Sredenšek (eds.)
University of Maribor Press

VENTILATION STATION NOP II: A NEW STEP FOR SAFE AND RELIABLE COAL MINING OPERATIONS

GREGOR JEROMEL, JANEZ ROŠER
Premogovnik Velenje d.o.o., Velenje, Slovenia
gregor.jeromel@rlv.si, janez.roser@rlv.si

Keywords: mine ventilation, NOP II Ventilation Station, coal mining, safety in mining, environmental impact

Ventilation in mines plays a crucial role in the safety and operational efficiency of mining operations, ensuring appropriate working conditions and managing risks associated with mine gases. The ventilation system in the Velenje Coal Mine, until recently, comprised the existing ventilation stations in Pesje and Šoštanj, which were built and commissioned more than forty years ago. With the inclusion of a new ventilation station at the beginning of 2024, we now operate with three ventilation stations: the Šoštanj Ventilation Station (main ventilator and backup ventilator, both of 1,800 kW power), the Pesje Ventilation Station (main ventilator of 800 kW power and backup ventilator of 600 kW power), and the new NOP II Ventilation Station (two ventilators of 1,000 kW power each). An interesting innovation is the ability for occasional parallel operation of two ventilators at the NOP II Ventilation Station, meaning simultaneous operation of the main and backup ventilators for greater system reliability. The ventilation system supplies the mine with approximately 27,000 m^3/min of fresh air, which is sufficient for ventilation needs.

The development of the NOP II Ventilation Station involved challenging design and construction projects, including a 393-metre-deep ventilation shaft, which represents the technically only acceptable solution for a long-term ventilation strategy ,along with the

existing Šoštanj Ventilation Station until the end of excavation and the completion of closure operations in the mine. The entire NOP II Ventilation Station facility, with all its devices, meets high and modern standards (BAT technology), which ensure primarily the safe production of coal and the safety of employees in the Velenje Coal Mine. With shorter ventilation paths and the high energy efficiency of the system, which provides efficiencies above 70%, the project represents a significant step forward in the development of more efficient and safer mining operations in the Velenje Coal Mine, as well as reducing its environmental impact. The new ventilation station will relieve the existing ventilation stations in Pesje and Šoštanj, thereby reducing emissions and unpleasant odours from both previous ventilation stations significantly, which are in close proximity to urban city centres.

6TH INTERNATIONAL CONFERENCE ENRE - ENERGY & RESPONSIBILITY
BOOK OF EXTENDED ABSTRACTS
S. Seme, K. Sredenšek (eds.)
University of Maribor Press

COAL HERITAGE: CONSERVATION AND PROMOTION OF THE COAL MINING HERITAGE AS EUROPE'S CULTURAL LEGACY

MATJAŽ KAMENIK,[1] TADEJA JEGRIŠNIK,[1] PAVLOS KRASSAKIS,[2] NIKOLAOS KOUKOUZAS,[2] KAMIL SZEWERDA,[3] DARIUSZ MICHALAK,[3] NICOLAS CHARLES,[4] LAURENT BECCALETTO,[4] ROBERT HILDEBRANDT,[5] SYLWIA JAROSŁAWSKA-SOBÓR,[5] HERNAN FLORES,[6] TANSEL DOGAN[6]

[1] Premogovnik Velenje d.o.o., Velenje, Slovenia
matjaz.kamenik@rlv.si, tadeja.jegrisnik@rlv.si
[2] Centre for Research and Technology, Hellas (CERTH), Maroussi, Greece
krassakis@certh.gr, koukouzas@certh.gr
[3] KOMAG Institute of Mining Technology, Gliwice, Poland
kszewerda@komag.eu (K.S.), dmichalak@komag.eu
[4] BRGM-French Geological Survey, Orléans, France
n.charles@brgm.fr; l.beccaletto@brgm.fr
[5] Central Mining Institute - National Research Institute, Katowice, Poland
rhildebrandt@gig.eu; sjaroslawska@gig.eu
[6] Research Center of Post-Mining, Technische Hochschule Georg Agricola (THGA), Bochum, Germany
Hernan.Flores@thga.de, Tansel.Dogan@thga.de

Keywords: mining and coal mining heritage, "fair just" transition, Web GIS, story map, Europe coal mining, mining museums, geo-heritage

Coal Heritage is an accompanying measure European project that focuses exclusively on the promotion of coal mining heritage in post-mining regions, and in regions where coal mining is facing transition. As coal mining heritage is a very typical example of industrial and geological heritage with a profound effect on a local, regional and national level, an initial analysis was done of an inventory and categorization of mining assets. In addition, a comparative analysis of national reports provided better insight into coal heritage management in Europe.

The overall goal of the Project is the development of an interregional network for the promotion and protection of coal mining heritage in mining regions. The goal aims to support local communities and their residents in the transition through the repurposing of coal mines. The general plan is to provide access to re-skilling programmes, create the potential to stimulate new economic activities in these areas and develop jobs in new economic sectors, especially in relation to the coal regions in transition (e.g., tourism).

To achieve wide promotion and to develop a dedicated strategy, the project will create a platform, the European Visual Map Journal (EVMJ), which is an interactive web GIS tool. In scope of the project there will be the collection, interactive presentation and dissemination of heritage assets of mining and post-mining coal areas on selected coal mining territories in Slovenia, Greece, Poland, France and Germany.

<EnRe>
energy & responsibility

ECOLOGY AND ENVIROMENTAL PROTECTION

6TH INTERNATIONAL CONFERENCE ENRE - ENERGY & RESPONSIBILITY
BOOK OF EXTENDED ABSTRACTS
S. Seme, K. Sredenšek (eds.)
University of Maribor Press

MARINE LITTER - FROM THE SLOVENIAN COAST TO THE OTRANTO GATE

NATALIJA ŠPEH
Faculty of Environmental Protection, Velenje, Slovenia
natalija.speh@fvo.si

Keywords: marine pollution, sea waste, plastic share, Adriatic Sea, Slovenian Coast

Marine litter (ML) is divided roughly into micro- (particles of anthropogenic origin smaller than 5 mm) and macro-waste (an object of anthropogenic origin larger than 5 cm) (Ministry of Natural Resources and Spatial Planning/MNRSP, 2022). Since 2014, Slovenia has been conducting pilot monitoring of marine litter on the sea surface, seabed, coastal sediments and marine organisms (fish and molluscs). Analyses to date have shown the presence of micro-waste (including microplastics) in both fish and shellfish. (National Institute of Biology/NIB).

In the period 2013-2017, the Institute for Water of the Republic of Slovenia (IzVRS), and 16 partner organizations from seven countries bordering the Adriatic Sea, with the coordination of the leading partner from Slovenia, the National Institute of Chemistry, monitored and recorded the deposition of marine macro-waste at four sites of coastal land between Ankaran and Piran.

The latest inventory in the Adriatic Sea concentrated on the Gulf of Trieste. A thorough examination of the Slovenian coastal region from Lazaret on the Italian border to Piran in 2023 has unveiled a persistent pattern of waste types consistent with earlier surveys. (NIB, IzVRS) Cigarette butts continue to dominate, detracting significantly from the scenic beauty of the landscape. The majority of the waste discovered is fragmented, degraded, and challenging to identify. A new observation is the flatfish.

Despite an evident increase in litter concentration along the coastline (MSF Directive 56/2008/EC), the overall pollution level of the Slovenian coast is deemed moderate (Špeh et al., 2021), with specific areas undergoing regular cleaning efforts, notably within protected zones.

References

Inštitut za vode RS (IzVRS). Projekt DeFishGear. http://www.izvrs.si/?s=defishgear

Marine Strategy Framework Directive (MSFD) 2008/56/EC (2008). https://www.eea.europa.eu/policy-documents/2008-56-ec

Ministry of Natural Resources and Spatial Planning/MNRSP (2022). Načrt upravljanja z morjem 2022-2027. https://www.gov.si/assets/ministrstva/MOP/Dokumenti/Voda/NUMO/NUMO_2022_2027.pdf

Nacionalni inštitut za biologijo (NIB). *Projekti*. https://www.nib.si/projektinib?view=project&id=425

Špeh, N., Lončarić, R., Breznik, K., Surić, M. (2021). Burden of the Coastal Area with Solid Waste in Kornati National Park (Croatia). V M. Krevs (ur.), *Hidden geographies, Key challenges in geography* (str. 153-170). Springer Nature. doi: 10.1007/978-3-030-74590-5_7.

6TH INTERNATIONAL CONFERENCE ENRE - ENERGY & RESPONSIBILITY
BOOK OF EXTENDED ABSTRACTS
S. Seme, K. Sredenšek (eds.)

University of Maribor Press

OVERCOMING CHALLENGES IN MICROPLASTIC SAMPLING IN WATER BODIES FOR CLIMATE NEUTRALITY AND GREEN TRANSITION

ALJOŠA KRAJNC, ANJA BUBIK
Faculty of Environmental Protection, Velenje, Slovenia
anja.bubik@fvo.si, akrajnc42@gmail.com

Keywords: microplastics, sampling methodology, surface water bodies, green transition, water pollution

The article aims to raise awareness about the importance of overcoming challenges in microplastic sampling in water bodies, and to highlight the role of such efforts in promoting climate neutrality and the transition towards a more environmentally sustainable future.

Improving microplastic detection helps us pinpoint pollution sources, potentially leading to better cleanup strategies, stronger policies and greater public awareness. This advances efforts toward a sustainable planet by reducing plastic waste and protecting aquatic ecosystems. Researchers face challenges in waterborne microplastics` sampling due to size variation, diverse chemical composition, environmental background noise and lack of standardised methodologies amongst some of the more pressing matters. Some of the approaches are an effort to standardise sampling methods, integrating automated sampling technologies and the use of analytical chemistry, and technologies such as FTIR spectroscopy, Raman microscopy and visual characterisation under magnification, to enhance the accuracy and efficacy of the obtained results.

We have tackled the challenges by designing a water pumping and filtration system that enables sampling of surface water bodies with a filtration chamber catching particles greater than 200 micrometres, and a flow meter for better analytical interpretation. Further goals in our efforts are the use of FTIR-ATR spectroscopy for identification of microplastic particles obtained from the sampling. The system's key advantage is to ensure measurement independence from water flow and sampling site depth, while offering control over filtered water volume, enhancing accuracy and representativeness, and it is mobile, easy to use and maintain, time and cost efficient, and adaptable for application in various water bodies.

6TH INTERNATIONAL CONFERENCE EnRe - ENERGY & RESPONSIBILITY
BOOK OF EXTENDED ABSTRACTS
S. Seme, K. Sredenšek (eds.)
University of Maribor Press

PREPARATION OF THE ACTION PLAN FOR THE DECARBONISATION OF A PRODUCTION COMPANY

GAŠPER GANTAR[1,2]

[1] Faculty of Environmental Protection, Velenje, Slovenia
gasper.gantar@fvo.si
[2] College of Industrial Engineering, Celje, Slovenia
gasper.gantar@fvo.si

Keywords: sustainable development, carbon footprint, decarbonisation, action plan, production

With the European climate rules, the European Union undertakes to become carbon neutral by 2050, with an intermediate goal of reducing emissions by 55% by 2030 compared to 1990. The demands of various customers, especially from the automotive industry, are even more ambitious.

The first step is to calculate the company's carbon footprint. It is carried out according to the ISO 16064-1 Standard or the GHG protocol. Only when the baseline is established can companies begin to set goals and prepare action plans for achieving those goals.

Secondly, the goals for reducing emissions must be determined. These goals must be set just ambitiously enough to meet the upcoming demands of customers. On the other hand, overly ambitious goals lead to unnecessary costs.

Finally, a list of activities must be prepared to achieve the set goals. Each proposed activity must also be evaluated. It is reasonable to divide the activities into three categories:

- Short-term: The activities that are cost-neutral, or their introduction will not result in high costs as to threaten the economic performance of the company;
- Medium-term: The activities that will be legally required, or are expected to be cost-acceptable;
- Long-term: The activities that have the greatest potential, but are based on technologies that are currently not yet ready for use, and their introduction is, for the time being, associated with unacceptably high costs.

These results can be used in sustainable communication with customers and achieving their requirements in the field of Sustainable Development.

6TH INTERNATIONAL CONFERENCE ENRE - ENERGY & RESPONSIBILITY
BOOK OF EXTENDED ABSTRACTS
S. Seme, K. Sredenšek (eds.)

University of Maribor Press

THE POSSIBILITY OF INCREASING THE AMOUNT OF RENEWABLE ENERGY SOURCES IN THE DISTRIBUTION NETWORK AND LOSS REDUCTION USING ACTIVE ELEMENTS

TANJA TAJNIK
Faculty of Environmental Protection, Velenje, Slovenia
tanjatajnik@gmail.com

Keywords: CSRD, ESRS, sustainability reporting, companies, EU

Corporate sustainability reporting is the process by which a company informs its stakeholders, including investors, customers, employees and the public, about its environmental, social and governance performance. We are at a time when society is facing major challenges in the areas of environmental degradation, social inequality and economic instability. Business must begin to realise its responsibility towards the environment, and move towards positive changes that lead to sustainable operations and a circular economy. The question is how EU companies are approaching the sustainability reporting aspect. Do they have strategies and plans for reporting?

The EU adopted the Non-Financial Reporting Directive (NFRD) in 2014, and this was the first legally binding obligation for companies to report non-financial information, and today it is being upgraded by the CSRD (Corporate Sustainability Reporting Directive). Environmental, social and corporate reporting (ESG) is therefore a core of the CSRD Directive, and will now be mandatory for around 17,000 of the 50,000 companies in the EU. The ESRS are European sustainability reporting Standards and are a key element of CSRD. For the first time, companies must report ESG information and sustainability

disclosures in a standardised, compatible and consistent form at EU level - just like financial reporting.

Our research focused on the link between various existing sustainability reports and CSRD guidelines and strategies. We analysed different EU sustainability reports and compared them with each other. We found that more recent reports are more in line with the CSRD Directive and contain more sustainability strategies.

Reporting is about assessing the company's sustainable performance and evaluating the process of achieving measurable goals set by the company. Sustainability reporting involves disclosing information about a company's activities, such as its environmental impact, social responsibility initiatives and corporate governance practices. It is also important to report on strategies and performance indicators and how the company manages ESG risks and opportunities. All sustainability reporting goals in the EU are based on the vision of creating a low-carbon and climate-resilient economy.

References

Dolmans M., Bourguignon G., Cibrario Assereto C., Dictus T. The Corporate Sustainability Reporting Directive: From "Non-Financial" to "Sustainability" Reporting (2021). LERT MEMORANDUM.

European Comission. 2022. Directive (EU) 2022/2464 of the European Parliament and of the Council of 14 December 2022 amending Regulation (EU) No 537/2014, Directive 2004/109/EC, Directive 2006/43/EC and Directive 2013/34/EU, as regards corporate sustainability reporting (Text with EEA relevance). Official Journal of the European Union, L 322/15, 16.12.2022.

Odobaša, R., & Marošević, K. 2023. EXPECTED CONTRIBUTIONS OF THE EUROPEAN CORPORATE SUSTAINABILITY REPORTING DIRECTIVE (CSRD) TO THE SUSTAINABLE DEVELOPMENT OF THE EUROPEAN UNION. *EU* and Comparative Law Issues and Challenges Series (ECLIC), 7, 593–612. https://doi.org/10.25234/eclic/27463

Massa L., Farneti F., Scappini B. 2015. Developing a sustainability report in a small to medium enterprise: process and consequences. Meditari Accountancy Research, Volume 23 (1).

Tobias E., Hampus F. 2023. Does Directive (EU) 2022/2426 foster sustainability reporting quality?: A quantitative study on the compliance with, and quality of, the cross-cutting and topical standards derived from Directive (EU) 2022/2464. Digitala Vetenskapliga Arkivet.

6TH INTERNATIONAL CONFERENCE ENRE - ENERGY & RESPONSIBILITY
BOOK OF EXTENDED ABSTRACTS
S. Seme, K. Sredenšek (eds.)
University of Maribor Press

HEAVY METAL CONTENT IN VEGETABLE GARDEN SOILS IN RELATION TO THEIR NATURAL BACKGROUND

BORUT VRŠČAJ, ANA STRMČNIK
Faculty of Environment Protection (FVO), Velenje, Slovenia
borut.vrscaj@fvo.si, a.strmcnik@gmail.com

Keywords: soil contamination, soil degradation, food safety, allotment gardens, soil pollution

Heavy metals (HM) are naturally present in soil[1] due to the weathering of the element-rich parent rock and by anthropogenic sources (industry, energy production, agriculture, traffic)[24]. The agricultural source of increased HM concentrations in soil are HM-containing fertilisers and pesticides. Agricultural soils are often considered polluted and are therefore subject to soil contamination monitoring for food safety reasons.

Allotments are particularly at risk from intensive gardening, the general overuse of fertilisers, soil conditioners often seen as a means of improving soil quality, in some cases the overuse or misuse of pesticides and in the past the use of coal ash. In some cases, landowners are also receiving untested and potentially polluted soils from elsewhere. Therefore, the soils of the vegetable/allotment gardens are generally considered to be 'highly anthropogenised'.

According to Slovenian legislation[5], the HM concentration is considered elevated if the HM concentration in the soil is above the limit immission value (LIV), polluted if it is above the warning immission value (WIV) and critically polluted if it is above the critical immission value (CIV).

The HM content in the soils of 20 allotment gardens in the village of Legen (Municipality of Slovenj Gradec, Carinthia) was analysed. The soil samples were dried, grinded and sieved in the FVO laboratory and analysed 'by Bureau Veritas Commodities (Canada) using Aqua Regia extraction to determine the 'pseudo-total content' for 37 elements (Ag, Al, **As**, Au, B, Ba, Bi, Ca, **Cd**, **Co**, **Cr**, **Cu**, Fe, Ga, **Hg**, K, La, Mg, **Mn**, Mo, Na, **Ni**, P, **Pb**, S, Sb, Sc, Se, Sr, Te, Th, Ti, TI, U, V, W, and **Zn** 10 of which (in the frame) are considered common HM soil contaminants.

The comparison of the HM concentrations in the garden soils with the well-known rich natural geochemical background of the area showed that the values for all compared metals, except Al, Fe, Ga, Sc, Th and Co, are higher than element natural backgrounds in the Eastern Alps and in Slovenia as a whole. The HM concentrations in the garden soils are within or slightly above the natural background values[1] but below the LIV with the exception of Pb and Zn in four gardens, where the concentrations exceed the WIV[6].

The garden soils in Legen village area have been anthropogenically enriched, most likely by the introduction of manure and, in one case, untested and contaminated soils from elsewhere. Most of the gardens are characteristically oversupplied with nutrients P and K; the soils are moderately enriched with soil organic matter and have an average acidity of pH 6.7, which means that soil is neutral.

References

Gosar, M. *et al.* Geochemical background and threshold for 47 chemical elements in Slovenian topsoil. *Geologija* **62**, 557 (2019).

Heavy Metals in Soils: Trace Metals and Metalloids in Soils and Their Bioavailability. (Springer, Dordrecht, Netherlands ; New York, 2013).

Nicholson, F. A., Smith, S. R., Alloway, B. J., Carlton-Smith, C. & Chambers, B. J. An inventory of heavy metals inputs to agricultural soils in England and Wales. *Sci. Total Environ.* **311**, 205219 (2003).

Birke, M. *et al.* GEMAS: Cadmium distribution and its sources in agricultural and grazing land soil of Europe Original data versus clr-transformed data. *J. Geochem. Explor.* **173**, 1330 (2017).

Republika Slovenija. Uredba o Mejnih, Opozorilnih in Kritičnih Imisijskih Vrednostih Nevarnih Snovi v Tleh= Decree on Limit, Warning and Crytical Immision Values of Contaminants in Soil (UL RS Št. 68/1996; 41/2004). 10 (1996).

Strmčnik, A. Variability of the content of heavy metals in the garden soil of a small rural settlement - the example of the Legen settlement [Variability of the content of heavy metals in the garden soil of a small rural settlement - the example of the Legen settlement]. (Fakulteta za varstvo okolja [Faculty of Environmental Protection], Velenje, 2024).

6TH INTERNATIONAL CONFERENCE ENRE - ENERGY & RESPONSIBILITY
BOOK OF EXTENDED ABSTRACTS
S. Seme, K. Sredenšek (eds.)
University of Maribor Press

A PMSG WIND TURBINE AND ENERGY STORAGE SYSTEMS FEATURING LOW-VOLTAGE RIDE-THROUGH COORDINATED CONTROL

PETER FRANTAR
Slovenian Environment Agency, Ljubljana, Slovenia
peter.frantar@gov.si

Keywords: water balance, climate change, climate scenarios, runoff, adaptation, Slovenia, mGROWA

The water balance is a key to understanding the water environment and sustainable water management. In Slovenia, several periodic water balances have been developed (Kolbezen, 1998; Frantar et al., 2008; Andjelov et al., 2015), and the last project is a result of work between the Environmental Agency and the Research Center Jülich in Germany (FZJ) - model mGROWA (Frantar et al., 2018a; Frantar et al., 2018b; Frantar et al., 2023). It is a deterministic water balance model with runoff as a water balance component showing the water quantity in a specific area over a designated time. Total runoff (Qn) is a part of precipitation that reaches the ground and does not evaporate, and is not retained in plants or soil. Total runoff flows overland or subsurface into watercourses. It is calculated from the basic equation of the water cycle balance: $Qn = P - ET + \Delta S$, where P represents precipitation, ET the actual evapotranspiration and ΔS the change in water storage (Herrmann et al., 2015; Frantar et al., 2023). The model was verified on the 1981-2010 hydrological discharge data for total runoff and groundwater recharge (Frantar et al., 2018b; Frantar et al., 2023). Respectively the mGROWA model is a robust regional water balance model enabling analyses of the impact of climate change on Slovenia's water balance, with runoff as one of major model outputs. This was also made within the OPS21 project (Bertalanič et al., 2018).

The runoff (almost equal to discharge) is a major component in hydropower plant production, and therefore essential for its long-term management. The present runoff state and the future runoff expectations up to the year 2100 in Slovenia will be presented at the EnRe Conference.

References

Andjelov M., Kunkel R., Susin J., Uhan J., Wendland F., 2015: Modelling and management of nitrate inputs into groundwater and surface water in Slovenia. 2nd International Interdisciplinary Conference on Land Use and Water Quality, 21-24 September 2015, Vienna

Bertalanič, R., Dolinar, M., Draksler, A., Honzak, L., Kobold, M., Kozjek, K., Lokošek, N., Medved, A., Vertačnik, G., Vlahović, Ž., Žust, A., 2018. Ocena podnebnih sprememb v Sloveniji do konca 21. stoletja. Sintezno poročilo – prvi del, Agencija RS za okolje. Ljubljana. Internet: www.meteo. si/uploads/probase/www/climate/text/sl/publications/OPS21_Porocilo.pdf

Frantar, P., ur. 2008: Vodna bilanca Slovenije 1971 – 2000. MOP-ARSO. Ljubljana. Dostopno na: www.arso.gov.si/vode/poro%C4%8Dila%20in%20publikacije/vodna%20bilanca/vodna_bilanca.html

Frantar, P., Herrmann, F., Andjelov, M., Dolinar, M., Bertalanič, R., Gartner, D., Sušnik, A., Gregorič, G., Petan, S., Miklavčič, J.G., Hitij, P., Jerman, J., Mikulič, Z., Medved, A., Bat, M., Ulaga, F., Jerovšek, J., Dvoršek, D., Cedilnik, J., Kobold, M., Uhan, J., Wendland, F. 2018a: mGROWA-Slovenia, Rezultati modela vodne bilance za Slovenijo -Water balance simulation results for the whole country of Slovenia. Zaključna predstavitev na Agenciji RS za okolje. Internet: https://meteo.arso.gov.si/uploads/probase/www/hidro/watercycle/text/sl/projects/mGROWA-SI/Prezentacija_mGROWA_201801a.pdf

Frantar, P., Herrmann, F., Andjelov, M., Draksler, A., Wendland, F. 2018b. Vodnobilančni model mGROWA--SI. 29. Mišičev vodarski dan. Internet: www.mvd20.com (15.5.2023).

Frantar, P., Andjelov, M., Herrmann, F., Wendland, F., 2023. Razvoj vodno bilančnega modela mGROWA v Sloveniji. Tretji slovenski kongres o vodah 2023, Zbornik, ur. Globevnik in Prešeren. Kamnik.

Herrmann, F., Keller, L., Kunkel, R., Vereecken, H., Wendland, F. 2015. Determination of spatially differentiated water balance components including groundwater recharge on the Federal State level – A case study using the mGROWA model in North Rhine-Westphalia (Germany). Journal of Hydrology: Regional Studies 2015; 4: 294–312.

Kolbezen, M., Pristov, J. 1998. Površinski vodotoki in vodna bilanca Slovenije. Hidrometeorološki zavod Slovenije. Ljubljana. Internet: www.arso.gov.si/vode/poro%C4%8Dila%20in%20publikacije/vodotoki_bilanca.html

6TH INTERNATIONAL CONFERENCE ENRE - ENERGY & RESPONSIBILITY
BOOK OF EXTENDED ABSTRACTS
S. Seme, K. Sredenšek (eds.)
University of Maribor Press

URBAN WASTEWATER - POTENTIAL FOR ENERGY AND NUTRIENT RECOVERY

NATAŠA URANJEK[1,2]
[1] Faculty of Environmental Protection, Velenje, Slovenia
natasa.uranjek@fvo.si
[2] Utility Company Velenje, Velenje, Slovenia
natasa.uranjek@kp-velenje.si

Keywords: urban wastewater, biogas production, energy self-sufficiency, phosphorus recycling, greenhouse gas emissions, water reuse, wastewater epidemiology

Municipal wastewater has always been considered as something that causes problems, diseases, eutrophication, bad smells; mainly something we don't want. In recent years, wastewater was recognized as a great source of nutrients, energy, and opportunities for reuse, but also it holds an infinite amount of information. The process of anaerobic digestion with the production of bio-methane, the use of heat or kinetic energy of the wastewater enables the production of renewable energy, which contributes to energy self-sufficiency and reduces greenhouse gas emissions. Sewage sludge is a source of phosphorus, nitrogen, and carbon, and can be recycled by using new treatment technologies. The key of importance is recycling of phosphorus, one of the three most important nutrients required for plant growth, since it was placed on the list of critical raw materials due to limited quantities of phosphate ore.

Properly purified and treated wastewater can be reused for irrigation, industry, and groundwater supply, thus reducing the pressure on fresh water. Wastewater also carries a lot of information about peoples` health and lifestyles. With the epidemiological analysis of wastewater, we can ensure effective, fast, and coordinated tracking of new types of viruses, and the examination of other important health parameters of the population without ethical dilemmas.

By applying new approaches to wastewater management, with the use of its hidden potential, we implement sustainable energy production, critical raw material recycling, reuse, and safety health measures, thus moving closer to closing the material and energy loop and moving towards a circular economy.

References

Elalami, D., Carrere, H., Monlau, F., Abdelouahdi, K., Oukarroum, A., & Barakat, A. (2019). Pretreatment and co-digestion of wastewater sludge for biogas production: Recent research advances and trends. *Renewable and Sustainable Energy Reviews*, *114*, 109287. https://doi.org/https://doi.org/10.1016/j.rser.2019.109287

European Commission, Directorate-General for Environment (2023). Circular economy – New tool for measuring progress, Publications Office of the European Union, https://data.europa.eu/doi/10.2779/1618

Ødegaard, H. (2016). A road-map for energy-neutral wastewater treatment plants of the future based on compact technologies (including MBBR), *Environmental Science Engeniring,* © Higher Education Press and Springer-Verlag Berlin Heidelberg

Schaum C. (ed.) (2018). Phosphorus: Polluter and Resource of the Future: Removal and

Recovery from Wastewater. *IWA-Publishing,* ISBN 978-1-78040-835-4, London

Sevillano, C. A., Pesantes, A. A., Pena Carpio, E., Martinez, E. J., & Gomez, X. (2021). Anaerobic Digestion for Producing Renewable Energy-The Evolution of This Technology in a New Uncertain Scenario. *Entropy (Basel)*, *23*(2). https://doi.org/10.3390/e23020145

Parravicini, V., Svardal, K., Krampe, J. (2016). Greenhouse Gas Emissions from Wastewater Treatment Plants. *Energy Procedia 97* , 246 – 253. https://doi.org/10.1016/j.egypro.2016.10.067

6TH INTERNATIONAL CONFERENCE ENRE - ENERGY & RESPONSIBILITY
BOOK OF EXTENDED ABSTRACTS
S. Seme, K. Sredenšek (eds.)
University of Maribor Press

HEAVY METAL CONTENT IN SOILS OF SELECTED AGRICULTURAL USES IN RELATION TO THEIR NATURAL BACKGROUND

BORUT VRŠČAJ, LUCIJA BOŽIJAK
Faculty of Environment Protection, Velenje, Slovenia
borut.vrscaj@fvo.si, lucija.bozijak@gmail.com

Keywords: soil contamination, agriculture, food safety, beer, soil quality

Heavy metals (HM) are naturally present in soil[1] due to weathering of the element-rich parent rock and anthropogenic sources (industry, agriculture, traffic, energy production,). The agricultural sources of increased HM concentrations in soil are HM-containing fertilisers and pesticides. Agricultural soils are often considered polluted, and are therefore subject to soil contamination monitoring for food safety reasons. Permanent crops are particularly at risk, due to the intensive and traditional (over)use of pesticides and fertilisers. Hop plantations are a special type of economically important permanent crop in the Lower Savinja region. The product, the dried hop cones, is mainly exported. The cultivation of hops requires intensive soil cultivation, fertilisation, and, above all, constant protection of the hop plants.

According to Slovenian legislation[5], the HM concentration is considered elevated if the HM concentration in the soil is above the limit emission value (LIV), polluted if it is above the warning emission value (WIV), and critically polluted if it is above the critical emission value (CIV).

The HM content was analysed in the soils of 10 hop plantations in the Lower Savinja region. The soil samples were dried, groud and sieved in the FVO laboratory ,and analysed

'by Bureau Veritas Commodities (Canada) using Aqua Regia extraction, to determine the 'pseudo-total content' for 37 elements (Ag, Al, **As**, Au, B, Ba, Bi, Ca, **Cd**, **Co**, **Cr**, **Cu**, Fe, Ga, **Hg**, K, La, Mg, **Mn**, Mo, Na, **Ni**, P, **Pb**, S, Sb, Sc, Se, Sr, Te, Th, Ti, TI, U, V, W, and **Zn** and Zn, 10 of which (in the frames) are considered common HM soil contaminants.

The HM concentrations in the soils of the hop plantations are within the natural background values[1] (below the LIV), with the exception of Cd, Cu and Zn, which are above the LIV in some cases. The Cd concentration is elevated in 90 % (it exceeds the LIV). The hop fields are not contaminated with Cd – the concentration does not exceed the WIV. The Cu concentration is within the natural background values in 20 % of the hop plantations (well below the LIV), 30 % is elevated (exceeds the LIV), while 50 % are polluted with Cu (Cu exceeds the WIV). The Zn concentration is below the LIV value in 80 % of the hop plantations, 10 % exceed the LIV value, while 10 % of the hop plantations are considered to be polluted with Zn (Zn exceeds the WIV value)[6].

As expected, we found that the soils of the hop plantations contain significantly increased, and, in some places, exceeded quantities of Cu and Zn, and, in some cases, also Cd. Elevated concentrations of HM may also be reflected in other parts of the environment, while the effects on food quality (i.e. elevated concentrations in beer) are not detected.

References

Gosar, M. *et al.* Geochemical background and threshold for 47 chemical elements in Slovenian topsoil. *Geologija* **62**, 5–57 (2019).

Heavy Metals in Soils: Trace Metals and Metalloids in Soils and Their Bioavailability. (Springer, Dordrecht, Netherlands ; New York, 2013).

Nicholson, F. A., Smith, S. R., Alloway, B. J., Carlton-Smith, C. & Chambers, B. J. An inventory of heavy metals inputs to agricultural soils in England and Wales. *Sci. Total Environ.* **311**, 205–219 (2003).

Birke, M. *et al.* GEMAS: Cadmium distribution and its sources in agricultural and grazing land soil of Europe — Original data versus clr-transformed data. *J. Geochem. Explor.* **173**, 13–30 (2017).

Republika Slovenija. *Uredba o Mejnih, Opozorilnih in Kritičnih Imisijskih Vrednostih Nevarnih Snovi v Tleh= Decree on Limit, Warning and Crytical Immision Values of Contaminants in Soil (UL RS Št. 68/1996; 41/2004)*. 10 (1996).

Božijak, L. Vsebnost težkih kovin v tleh izbranih hmeljišč Spodnje Savinjske doline [The content of heavy metals in the soil of selected hop farms in the Lower Savinja Valley]. (Fakulteta za varstvo okolja [Faculty of Environmental Protection], Velenje, 2024).

<EnRe>
energy & responsibility

STUDENT SECTION

6TH INTERNATIONAL CONFERENCE ENRE - ENERGY & RESPONSIBILITY
BOOK OF EXTENDED ABSTRACTS
S. Seme, K. Sredenšek (eds.)

University of Maribor Press

METHODS FOR RECYCLING PHOTOVOLTAIC MODULES AND ELEMENT RECOVERY PROJECTIONS IN SLOVENIA

MANJA OBREZA,[1] NEJC FRIŠKOVEC,[1] KLEMEN SREDENŠEK,[1]
SEBASTIJAN SEME [1,2]

[1] University of Maribor, Faculty of Energy Technology, Krško, Slovenia
manja.obreza@student.um.si, nejc.friskovec@student.um.si,, klemen.sredensek@um.si, sebastijan.seme@um.si
[2] University of Maribor, Faculty of Electrical Engineering and Computer Science, Maribor, Slovenia
sebastijan.seme@um.si

Keywords: photovoltaic modules, photovoltaic modules recycling, waste management, end-of-life cycle, environmental impact

Photovoltaic technology is a promising solution for enhancing energy security and combating climate change. Its market is swiftly expanding, with projections foreseeing continued global growth. The anticipated global photovoltaic installed capacity is set to reach approximately 4500 GW by 2050 (IRENA, 2023). Beyond its evident benefits for energy security and climate resilience, photovoltaic technology stands out as one of the most eco-friendly options among all energy and electricity generation methods. This distinction becomes particularly pronounced when considering its entire life cycle, including end-of-life handling. Hence, ensuring proper management at the end of its lifespan becomes imperative for maintaining the integrity of clean energy technologies (IRENA, 2016). However, as the lifespan of photovoltaic modules draws to a close, effective recycling methods become crucial to minimize environmental impact and resource depletion. One of the primary challenges in recycling photovoltaic modules is the need for standardized procedures, underscoring the importance of implementing appropriate regulatory and technological approaches tailored to the conditions of each country. While the European Union has adopted specific directives in this area, other parts

need more adequately defined legislation (Sharma, 2019). Photovoltaic modules can be fabricated from various materials, yet most of the market relies on monocrystalline silicon cell technology, typically with a thickness between 150 and 180 μm. A monocrystalline photovoltaic module comprises silicon cells and an antireflective layer of silicon nitride (SiNx), with the front electrode of silver and the back electrode of aluminum (Mulazzani, 2022). The full paper reviews recent advancements in photovoltaic module recycling technologies, focusing on predicting the potential mass of specific elements that could be recovered through recycling in Slovenia, considering the installed capacity of solar power plants.

References

IRENA, IEA PVPS. (2023). Strategic PV Analysis and Outreach, *Publications*
IRENA, IEA PVPS (2016). End-of-life-Management: Solar Photovoltaic Panels, *Publications*
Sharma A., et al. (2019). Global review of policies & guidelines for recycling of solar PV modules, International Journal of Smart Grid and Clean Energy. 8, 567-610. doi: 10.12720/sgce.8.5.597-610
Mulazzani A., et al. (2022). Recycling c-Si PV Modules: A Review, a Proposed Energy Model and a Manufacturing Comparison, Energies 2022. 15, 8419. doi: 10.3390/en15228419

6TH INTERNATIONAL CONFERENCE EnRe - ENERGY & RESPONSIBILITY
BOOK OF EXTENDED ABSTRACTS
S. Seme, J. Avsec, K. Sredenšek (eds.)
University of Maribor Press

CABLE INSULATION AGING ANALYSIS WITH X-RAY FLUORESCENCE SPECTROMETRY

NEJC FRIŠKOVEC,[1] MANJA OBREZA,[1] MARKO PIRC,[2] KLEMEN SREDENŠEK,[1] ZDRAVKO PRAUNSEIS[1]

[1] University of Maribor, Faculty of Energy Technology, Krško, Slovenia
nejc.friskovec@student.um.si, manja.obreza@student.um.si, klemen.sredensek@um.si, zdravko.praunseis@.um.si
[2] Nuclear Power Plant Krško, Krško, Slovenia
marko.pirc@nek.si

Keywords: cable aging, polymer electrical insulation, x-ray fluorescence spectrometry, predictive maintenance, acceptance testing

Electrical cables and their insulation are considered an elementary part of the electro-energetic system, and all electric or electronic systems utilize electrical power for operation. Despite their essential role, they are often taken for granted and not maintained adequately (Ilie, 2011). Aging, characterized by the degradation of material and the weakening of mechanical, electrical, and chemical properties of the polymer insulation, results in the destruction of the cable. Typically, cables are designed to outlive the life expectancy of the systems they operate. Issues arise when accelerated aging occurs due to external factors, such as high or low temperatures, high humidity, the presence of oil, aggressive chemicals, UV light, or ionizing irradiation (Mustafa, 2020). These issues include an electrical field, high frequency, and heat resulting from the heating conduction inside the cable (Li, 2016).

Standard tests exist for the analysis of cable properties, such as measurements of insulation resistance, dielectric losses, partial discharges, time-domain reflectometry, and frequency-domain reflectometry, each with its weaknesses and benefits (Lin, 2020). In addition to electrical measurements, mechanical tests are also conducted, such as the intender

modulus, based on the tensile test and measurements of the cable diameter (Anandakumaran, 2007). Electrical and mechanical changes are caused by chemical changes in the material resulting from molecule decay and the extraction of molecules due to these changes. Techniques such as differential dynamic calorimetry, FTIR, and X-ray fluorescence spectrometry are employed for these purposes (Pirc, 2018). XRF aims to estimate the degradation of polymer insulation based on measurements of the presence or absence of individual atoms to establish acceptance criteria.

References

Ilie S., Setnescu R, Lungulescu E.M., Marinescu V., Ilie D., Setnescu T., Mareş G. (2011). Investigations of a mechanically failed cable insulation used in indoor conditions, *Polymer Testing*, 30, 173-182. doi: 10.1016/j.polymertesting.2010.11.016

Mustafa E., Afia R.S.A, Tamus Z.Á. (2020). Condition Monitoring Uncertainties and Thermal-Radiation Multistress Accelerated Aging Tests for Nuclear Power Plant Cables: A Review, Periodica polytechnica electrical engineering and computer science, 64, 20-32. doi: 10.3311/PPee.14038

Li J., et al. (2016). The effect of self-producing heat and external radiation on the insulating property of wire, Procedia Engineering. 135, 151-159. doi: 10.1016/j.proeng.2016.01.097

Lin L., et al (2020), Aging Life Evaluation of Coal Mining Flexible EPR Cables Under Multi-Stresses, v IEEE Access, 8, 53539-53546. doi: 10.1109/ACCESS.2020.2981359

Anandakumaran K. (2007). Aging and condition monitoring studies of composite insulation cables used in nuclear power plants, IEEE Transactions on Dielectrics and Electrical Insulation, let. 14, 227-237. doi: 10.1109/TDEI.2007.302891

Pirc M., et al (2018). Cable aging monitoring with differential scanning calorimetry (DSC) in nuclear power plants, Transactions of FAMENA, 42, 87-98. doi: 10.21278/TOF.42Si108

6TH INTERNATIONAL CONFERENCE ENRE - ENERGY & RESPONSIBILITY
BOOK OF EXTENDED ABSTRACTS
S. Seme, K. Sredenšek (eds.)
University of Maribor Press

THE IMPACT OF RESIDENTIAL ELECTRICAL ENERGY GENERATION, CONSUMPTION, AND STORAGE ON DISTRIBUTION GRID VOLTAGE

EVA SIMONIČ,[1] SEBASTIJAN SEME,[1,2] KAREL ZUPANC,[3] KLEMEN SREDENŠEK[1]

[1] University of Maribor, Faculty of Energy Technology, Krško, Slovenia
eva.simonic@um.si, sebastijan.seme@um.si, klemen.sredensek@um.si
[2] University of Maribor, Faculty of Electrical Engineering and Computer Science, Maribor, Slovenia
sebastijan.seme@um.si
[3] Elektro Gorenjska, d. d., Kranj, Slovenia
karlo.zupanc@elektro-gorenjska.si

Keywords: low-voltage distribution grid, photovoltaic system, heat pump, electrical energy storage system, Monte Carlo method

This paper analyzes the dynamics of residential electrical energy generation and consumption within a low-voltage distribution grid. Motivated by the widespread adoption of distributed energy resources and the escalating electrification of residential heating systems, the study delves into the operational impacts of photovoltaic systems and heat pumps. Additionally, it explores the potential advantages of integrating electrical energy storage systems as a complement to photovoltaic systems.

The analysis is conducted through simulations of demanding operational scenarios arising from annually occurring extreme weather conditions. Employing MATLAB Simulink, a simulation model is developed to replicate a real low-voltage distribution grid feeder, providing the simulation environment. The key deterministic input parameters encompass grid topology and consumer load time series data, spanning one year with a resolution of 15 minutes.

Mathematically modeled and weather-dependent photovoltaic systems and heat pumps are allocated to residential consumers via the Monte Carlo method, ensuring a randomized distribution. The voltage amplitude at the consumer level is observed as the criterion for assessing power supply quality. The analysis explores the impact of integrating these newly introduced systems on the daily voltage profile. Furthermore, photovoltaic systems are updated with electrical energy storage systems, revealing promising potential in augmenting low-carbon technologies within residential distribution grids.

The paper emphasizes the synergy among systems and combinations of technologies to optimize residential energy systems and enhance grid stability. It explores innovative pathways towards the integration of renewables and advancing to the goals of sustainability.

References

Navarro-Espinosa A. and Ochoa L. F. (2016). Probabilistic Impact Assessment of Low Carbon Technologies in LV Distribution Systems. IEEE Transactions on Power Systems, vol. 31, no. 3, pp. 2192-2203.

Villavicencio Gastelu J., Boas Leite J., Melo Trujillo J. D. (2020). Stochastic Analysis of Hosting Capacity in Low-Voltage Networks with PV-plus-Storage Systems. IEEE PES Transmission & Distribution Conference and Exhibition - Latin America, pp. 1-6.

Afkousi-Paqaleh M., Rigoni V., Wilson C., Hewitt N., Flynn D., and Keane A. (2021). Network Limits on Residential Heat Pump Capacity as an Enabling Technology towards Renewables Integration. The 9th Renewable Power Generation Conference, Online Conference, pp. 265-270.

Cenký M., Bendík J., Eleschová Ž., Beláň A., Cintula B., and Janiga P. (2022). Stochastic Analysis of Battery Storage Systems Integration to the Real Distribution Network with Variable Penetration Levels of PV Systems. 2022 International Conference on Smart Systems and Technologies (SST), Osijek, Croatia, pp. 237-242.

6TH INTERNATIONAL CONFERENCE ENRE - ENERGY & RESPONSIBILITY
BOOK OF EXTENDED ABSTRACTS
S. Seme, J. Avsec, K. Sredenšek (eds.)

University of Maribor Press

THE IMPACT OF LEGISLATIVE CHANGES ON THE ELIGIBILITY OF AN INVESTMENT IN A PHOTOVOLTAIC SYSTEM AND ELECTRICITY STORAGE

EVA BAHČIČ,[1] EVA SIMONIČ,[2] KLEMEN SREDENŠEK,[2] SEBASTIJAN SEME[2,3]

[1] GEN Group, Krško, Slovenia
eva.bahcic@gen-energija.si
[2] University of Maribor, Faculty of Energy Technology, Krško, Slovenia
eva.simonic@um.si, klemen.sredensek@um.si, sebastijan.seme@um.si
[3] University of Maribor, Faculty of Electrical Engineering and Computer Science, Maribor, Slovenia
sebastijan.seme@um.si

Keywords: photovoltaic system, electricity storage, energy self-sufficiency, investment eligibility, legislative and market changes

In this paper, an in-depth examination is conducted on the intricacies and operational dynamics of integrating a photovoltaic system with an electricity storage unit, with a particular focus on assessing the economic feasibility and practicality of moving towards energy self-sufficiency. This investigation is especially pertinent given the current climate of evolving Regulations and fluctuating market conditions. The paper analyzes the annual electricity consumption and production patterns of a residential setup equipped with both systems` solution methodically, aiming to shed light on the efficiency and sustainability of such systems.

By gathering and analyzing data on the electricity production by the photovoltaic system meticulously, alongside detailed monitoring of the household's electricity consumption in fifteen-minute intervals, the study sets out to determine the optimal specifications for the electricity storage unit accurately.

Moreover, the paper delves into the formation of electricity pricing schemes, a process guided by the stringent Directives of the Energy Act and the Act on the promotion of the use of renewable energy sources. This involves a nuanced consideration of both existing and newly introduced methodologies for calculating network charges, which vary significantly across different time periods.

Through a comprehensive techno-economic evaluation, the paper aims to provide critical insights into the feasibility of achieving self-sufficiency through such systems under various conditions. Additionally, it explores the synergistic integration of electricity storage and photovoltaic systems, highlighting how these technologies can be combined effectively to enhance energy independence and sustainability. This thorough analysis not only underscores the potential economic benefits, but also emphasizes the environmental impact, marking a significant contribution to the discourse on renewable energy and self-sufficiency.

References

Act on the Promotion of the Use of Renewable Energy Sources, number 121/2021, 189/2021, 29/2022 – ZUOPVCE, 121/2022 – ZUOKPOE, 158/2022 – ZNPOVCE

Electricity Supply Act, number 172/2021, 121/2022 – ZUOKPOE, 158/2022 – ZNPOVCE

Jin Y., Lv H., Yang A., Liu M., Chen B., Xie Y., Chen Q., Chen T. (2020), Applications of Lithium-Ion Batteries in Grid-Scale Energy Storage Systems, Transactions of Tianjin University volume, vol. 26, pp 208-217.

Mitali J., Dhinakaran S., Mohamad A.A. (2022), Energy storage systems: a review, Energy Storage and Saving, vol. 1, no. 3, pp 166-216.

Mohammadi-ivatloo B., Javadi S., Khodaei A. R., Denhavi H. Abdi E. (2017), Energy storage systems, Distributed generation systems, pp 333 - 368.

Zhang Y., Ma T., Yang H. (2022), Grid-connected photovoltaic battery systems: A comprehensive review and perspectives, Applied Energy, vol 328, pp 120182.

6TH INTERNATIONAL CONFERENCE EnRe - ENERGY & RESPONSIBILITY
BOOK OF EXTENDED ABSTRACTS
S. Seme, K. Sredenšek (eds.)
University of Maribor Press

QUALITY CONTROL IN ROBOTIC WELDING OF STEEL SURFACES

LUKA PEROVIĆ,[1] KLEMEN SREDENŠEK,[1] ZDRAVKO PRAUNSEIS[1]
University of Maribor, Faculty of Energy Technology, Krško, Slovenia
luka.perovic@student.um.si, klemen.sredensek@um.si, zdravko.praunseis@um.si

Keywords: joining of materials, welding, experimental testing, robotic welding, chemical analysis

Welding unites separate pieces into a single, unified entity known as a weldment. This process applies to various materials, including metals, polymers, glasses, ceramics, carbides, composites, and more. It is possible to weld both metals and non-metals together. Broadly speaking, welding techniques for metal materials fall into two categories: pressure welding and fusion welding. With the global market leaning increasingly towards automated production, Robotics have become a staple in various technological and manufacturing processes, due to their high efficiency. The push towards automation is motivated primarily by the pursuit of quality, cost reduction, and worker relief. Although robotic welding is still evolving, it is becoming more prevalent in numerous companies. Robotic welding is characterized by its use of advanced, directionally programmed robots, noted for their dependability. Incorporating robots into the welding process enhances both the reliability and quality of operations significantly, as these robots can operate continuously for 24 hours or longer. This enables companies to achieve superior quality, increased productivity, and reduced production costs. Robotic welding is particularly beneficial for large-scale projects, due to its high reproducibility and minimal error rate, provided that the robots are programmed correctly. The focus of this paper will be on single-wave welds on flat plates. Such welds are commonly employed in real-world applications, to mend damaged energy component surfaces and to improve the mechanical properties of the underlying material.

6TH INTERNATIONAL CONFERENCE ENRE - ENERGY & RESPONSIBILITY
BOOK OF EXTENDED ABSTRACTS
S. Seme, J. Avsec, K. Sredenšek (eds.)

University of Maribor Press

AUTOMATED WELDING TECHNOLOGIES FOR TUBULAR STEEL FABRICATION

ALEKSA RADOVANOVIĆ, KLEMEN SREDENŠEK, ZDRAVKO PRAUNSEIS
University of Maribor, Faculty of Energy Technology, Krško, Slovenia
aleksa.radovanovic1@student.um.si, klemen.sredensek@um.si, zdravko.praunseis@um.si

Keywords: robotic welding, pipe weld joint, microhardness, chemical analysis, heat-affected area

The aim of this paper is centered around the exploration and assessment of the efficiency and quality inherent in the automated welding process for the purpose of uniting tubular steel components. A critical part of the study involved a comparative analysis between traditional manual welding techniques and the cutting-edge advancements offered by robotic welding. This examination extended to evaluating the impact of robotic welding on the mechanical properties of the welds, specifically focusing on their hardness and toughness. Additionally, the research delved into the microhardness of different segments within the welded joint, encompassing the base material, the heat-affected zone, and the weld metal itself. Moreover, the thesis highlighted the significance of meticulous material preparation prior to welding, and underscored the need for finely tuned optimization of the welding equipment's parameters. Through this comprehensive analysis, the research aimed to provide insights into the advancements in welding technology, and their implications for the fabrication of tubular steel structures.

6TH INTERNATIONAL CONFERENCE ENRE - ENERGY & RESPONSIBILITY
BOOK OF EXTENDED ABSTRACTS
S. Seme, K. Sredenšek (eds.)

University of Maribor Press

ENERGY RENOVATION OF CULTURAL HERITAGE ON A CASE STUDY: VILLA ROŽLE

UROŠ MIĆIĆ, ZDRAVKO PRAUNSAIS, IZTOK BRINOVAR
University of Maribor, Faculty of Energy, Velenje, Slovenia
uros.micic@student.um.si, zdravko.praunsais@um.si, iztok.brinovar1@um.si

Keywords: Cultural Heritage, Villa Rožle, energy renovation, energy performance certificate, energy efficiency.

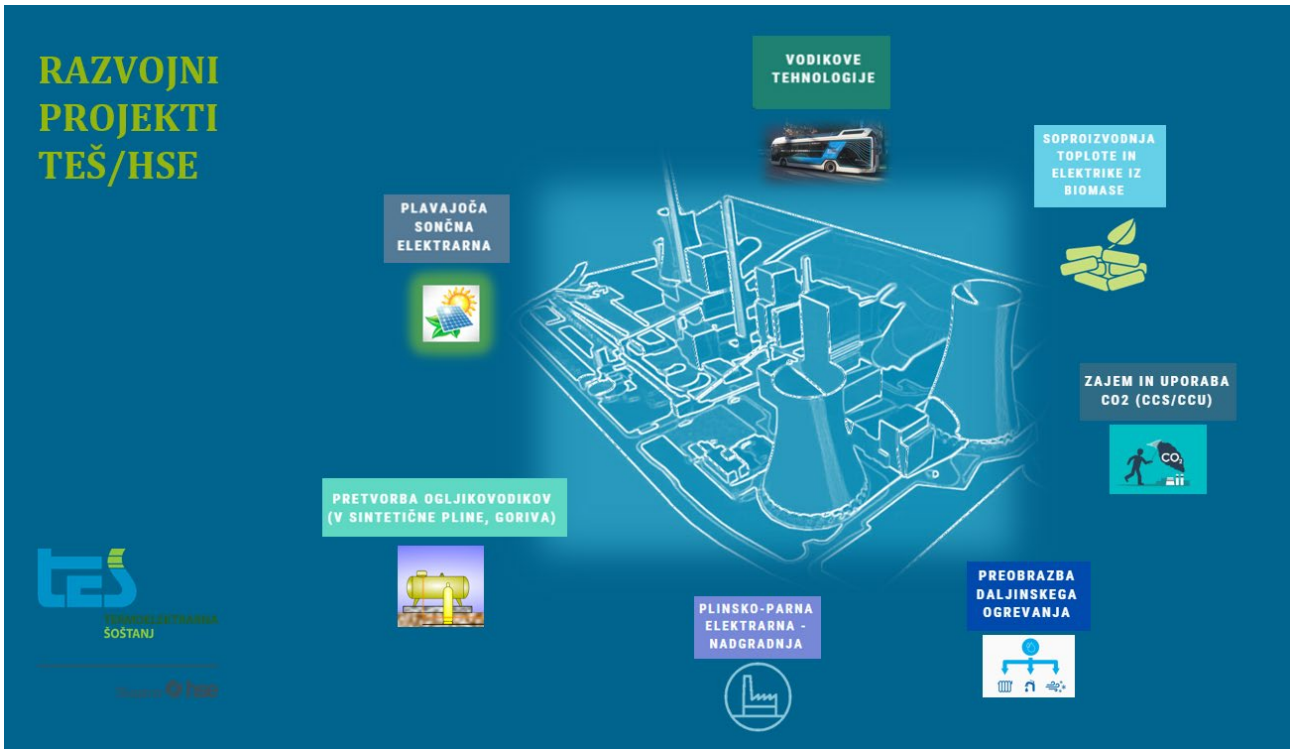
I the thesis presents the energy renovation of architectural heritage, using the example of Villa Rožla in Velenje. The legal background and basic concepts in energy renovation and cultural heritage protection are described. As part of the Diploma thesis, an analysis of the building's energy efficiency was conducted, for the state before and after the renovation. The effects of energy renovation were analyzed, and both calculated and measured energy certificates were produced. The results of the conducted analyses confirm that the renovation was logical and had numerous positive effects.

References

Bojan Purg (2015) "Detajlni energetski pregled – Vila Rožle", Velenje, 2015
KSSENA(Zavod Energetska agencija za Savinjsko, Šaleško, Koroško, „Elaborat Učinkovitosti izvedenih ukrepov za doseganje energetske učinkovitosti za Vilo Rožle“ TAMPOTISK, trgovina, storitve in proizvodnja d.o.o., Velenje, 2015.
Ministrstvo za okolje in prostor, „Tehnična semrnica TSG-1-004:2010“ 22. 06. 2010
Ministrstvo za kulturo, „SMERNICE za energetsko prenovo stavb kulturne dediščine“ November 2016.
E. Sklad, „ENERGETSKO UČINKOVIT OVOJ STAVBE“ 2020.

6TH INTERNATIONAL CONFERENCE ENRE - ENERGY & RESPONSIBILITY
BOOK OF EXTENDED ABSTRACTS
S. Seme, K. Sredenšek (eds.)

University of Maribor Press


RAZVOJNI PROJEKTI TEŠ/HSE
VODIKOVE TEHNOLOGIJE
SOPROIZVODNJA TOPLOTE IN ELEKTRIKE IZ BIOMASE
PLAVAJOČA SONČNA ELEKTRARNA
ZAJEM IN UPORABA CO2 (CCS/CCU)
PRETVORBA OGLJIKOVODIKOV (V SINTETIČNE PLINE, GORIVA)
PREOBRAZBA DALJINSKEGA OGREVANJA
PLINSKO-PARNA ELEKTRARNA - NADGRADNJA
ŠOŠTANJ


PREMOGOVNIK
VELENJE
Skupina hse
149 LET
ZANESLJIVE OSKRBE Z ELEKTRIČNO
ENERGIJO IZ NAŠEGA PREMOGA

6TH INTERNATIONAL CONFERENCE ENRE - ENERGY & RESPONSIBILITY

BOOK OF EXTENDED ABSTRACTS

SEBASTIJAN SEME, KLEMEN SREDENŠEK (EDS.)
University of Maribor, Faculty of Energy Technology, Krško, Slovenia
sebastijan.seme@um.si, klemen.sredensek@um.si

In the context of escalating climate challenges, the EnRe conference is dedicated to exploring pathways to climate neutrality and the sustainable green transition. The conference is focused on the development and implementation of innovations supporting the transformation of energy systems, industrial systems, and living systems, all with the goal of creating a sustainable future with net-zero emissions. The conference brings together experts, researchers, policymakers, and business leaders to share their experiences, research, and visions. The aim of the conference is to foster collaboration and exchange of ideas, and to collectively develop comprehensive approaches and strategies for achieving climate neutrality. This conference is not just a knowledge exchange, but also a platform for encouraging concrete actions that will ensure a greenerand more sustainable future for our next generations to come.

DOI
https://doi.org/
10.18690/um.fe.2.2024

ISBN
978-961-286-863-5

Keywords:
alternative energy systems, dynamic tariffing, electrical machines and drives, energy conversions, financing energy projects, nuclear energy, conventional energy systems, climate changes - climate pan, mathematical methods in engineering, micro and nano energy, low-carbon technologies and strategies, renewable energy technologies heating and cooling systems, smart buildings, cities and networks, policies and strategies for renewable energy sources, energy efficiency and the climate

University of Maribor Press

University of Maribor

Faculty of Energy Technology

21st May 2024, Velenje, Slovenia