
ENERGETIKA
2026
MEPSO
ZEMAK



Publishes AD MEPSO
ul.Maksim Gorki No 4, Skopje
Republic of North Macedonia
www.mepso.com.mk

General Director:
Prof.D-r Burim Latifi
Prepeared by:
Irina Daskalovska Kjosevska
Violeta Z. Stojanovska

OCTOBER 2026

INTODUCTION

Energy transition, accelerated RES development, the implementation of new technologies, and consumption changes place more serious demands on transmission systems. In an environment characterized by dynamic changes and a growing need for a secure, reliable, and sustainable electricity supply, developing and modernizing the transmission network is a key prerequisite for a successful energy transition.

These challenges were at the center of the international conference ENERGETIKA 2026, organized by ZEMAK, which serves as a platform for exchanging knowledge, experience, and professional perspectives among energy companies, engineers, researchers, and the academic community. The conference provided an opportunity to present current solutions, technological advances and practical experience contributing to the development of a more secure, efficient, and sustainable energy sector.

For MEPSO, as the transmission system operator, active participation in such professional gatherings offers an opportunity not only to share the knowledge and experience gained through its day-to-day operations, but also to contribute to professional dialogue on current challenges and the future of the power sector.

This special electronic edition is dedicated to MEPSO's participation in ENERGETIKA 2026. It brings together addresses by Borko Aleksoski, President of ZEMAK, and Burim Latifi, Director General of AD MEPSO, as well as abstracts of professional and scientific papers prepared by our colleagues. The contributions cover various aspects of the operation, planning, management, and enhancement of the transmission system, reflecting the expertise, professional experience, and commitment of MEPSO employees to continuous professional development and the application of modern engineering approaches.

We believe this edition will inspire new ideas, encourage professional debate, and create opportunities for cooperation, all toward a common goal: developing a modern, secure, and sustainable transmission system equipped to meet future needs.

ЗЕМАК

THE ENERGY SECTOR IN TRANSFORMATION: CHALLENGES, SOLUTIONS, AND NEW PERSPECTIVES

Speech by ZEMAK President Borko Aleksoski at the International Conference "ENERGETIKA" 2026

The energy sector is undergoing profound change, driven by technological development, new regulatory frameworks, and the imperative of sustainability, reshaping electricity generation, transmission, storage, and consumption. For the Macedonian energy sector, these changes represent both a challenge and an opportunity to build a more modern, flexible, and competitive transmission system. The rapid growth of solar power plants and wind farms has confirmed the importance of renewable sources, yet integrating them raises questions about stability, flexibility, and efficient system management.

In this context, a clear and predictable regulatory framework, aligned with European energy policy, is an essential precondition for investment, the introduction of new technologies, and the development of a competitive energy market. One key priority is developing energy storage systems, which enable better use of RES and greater system flexibility. At the same time, European decarbonization policies, including the CBAM mechanism, highlight the need to reduce emissions, improve energy efficiency, and safeguard domestic industry's competitiveness.

Complex challenges demand cooperation among institutions, energy companies, regulators, industry, and the academic community. They require the exchange of practical experience, expert argumentation, and research, as well as continuous professional



development. The contributions of engineers, researchers, and specialists are especially important, as their analyses and proposed solutions enable better understanding of the challenges and knowledge- and expertise-based decision-making.

All the above-mentioned points build the importance of "ENERGETIKA 2026", organized by the Association of Energy Professionals of Macedonia (ZEMAK). It serves as a platform to bridge knowledge and practice, present new achievements, and open discussions on the future of the energy sector. ZEMAK will continue to fulfill its role in connecting the energy profession, science, and practice, convinced that a shared approach and the application of modern technologies are key to developing a secure, flexible, and sustainable transmission system capable of meeting the demands of the energy transition and future economic development.

THE ENERGY TRANSITION REQUIRES A TRANSMISSION NETWORK READY FOR THE FUTURE

Message from the Director General of AD MEPSO, Assist. Prof. Burim Latifi, PhD, on the company's participation in ZEMAK 2026



The energy transition is no longer a choice but a process that demands timely and responsible implementation, without jeopardizing the security, stability, and quality of the electricity supply. In this process, the transmission network plays a strategic role, as it underpins the integration of new generation capacity, industrial development, and long-term energy security. Increased generation from renewable sources, the development of energy storage systems, and the digitalization of system management all call for a flexible, modern grid. At the same time, the growing needs of industry and data centers underscore the importance of available transmission capacity and supply quality. Therefore, coordinated development of generation and the transmission network, together with stronger regional interconnection, is indispensable for the secure and efficient functioning of the energy sector.

A successful energy transition depends on competitiveness, investment, and economic development. A stable and predictable system is needed for Macedonian companies to meet new market and regulatory requirements, one that rests on cooperation among institutions, regulators, energy companies, investors, and the academic community. In this spirit, we value the role of ZEMAK and of the "ENERGETIKA 2026" conference as a platform for exchanging knowledge, experience, and practical solutions. The papers by MEPSO colleagues presented in this electronic edition attest to their expertise, professional experience, and commitment to advancing the power transmission system.

MEPSO is committed to continuing the modernization and digitalization of the transmission network and strengthening



regional interconnection to provide infrastructure ready for new energy and industrial needs. I believe that the exchange of knowledge and experience encouraged by ZEMAK will spark new ideas, cooperation, and solutions applicable in practice. Our obligation is to develop the grid today so that it can respond securely and efficiently to the needs of tomorrow's energy sector.



MEPSO - ZEMAK 2026

AI Data Centers and the Transmission Grid: Challenges and Opportunities for Macedonia

Kliment Naumovski, Aleksandar Paunovski

In this paper are presented some characteristics of interaction between data centers and power system, more specifically, with the transmission grids: what kind of challenge is their integration in the grid, how European transmission operators are responding through new connection requirements (e.g. voltage regulation, ride-through capability), how these trends relate to MEPSO's concept of 400 kV energy hubs, planned first for renewable integration and later for data centers. It also considers whether data centers could help address the high voltages observed during light spring loading.





Energy Characteristics of AI Data Centers

Kliment Naumovski, Aleksandar Paunovski

Electricity demand from data centers is growing rapidly, driven largely by artificial intelligence. According to ENTSO-E (May 2026), European data center consumption is expected to grow by over 70% between 2025 and 2030, concentrated in hyperscale and scale-colocation facilities of tens to hundreds of megawatts. This paper introduces the hot topic of emerging data centers from the aspects of power system and transmission grids.



AMR/MDM System

Biljana Prodanovic, Dragan Vlajkinovski

The modern power system relies on the timely collection, processing, and analysis of accurate and reliable metering data. In this context, Automatic Meter Reading (AMR) and Meter Data Management (MDM) systems enable the automated remote collection, storage, and management of data from metering points. This paper analyzes the application of an AMR/MDM system for monitoring and presenting the electricity system status in the Republic of North Macedonia on a daily, monthly, and annual basis. Particular attention is given to the processing of Load Profile data, the identification of maximum and minimum load levels, and the generation of reports. The practical example is based on the application of the IDSpecto system and access to metering data from the transmission network. The results confirm the importance of AMR/MDM systems for the automation, analysis, and improved management of electricity metering data.



Transition from NTC to Flow-Based Cross-Border Transmission Capacity Calculation in Southeast Europe: An Analysis for North Macedonia

Zhivorad Serafimoski, Ivana Stefanovska, Nenad Jovanovski, Riste Micevski



Transmission system operators in Southeast Europe are currently facing a strategic transition from the Net Transfer Capacity (NTC) concept to the Flow-Based capacity calculation methodology. This paper provides a quantitative assessment of the impacts of this transition on the power system of North Macedonia, utilizing real-world operational data. The analysis is conducted across 287 hourly snapshots of the pan-European Common Grid Model (CGM) for the period from March 26 to April 6, 2026, with each individual model encompassing approximately 23,700 nodes and 33,000 branches. For the purposes of this research, an open-source computational module was developed to derive Power Transfer Distribution Factors (PTDFs), define Critical Network Elements under contingency (CNECs) according to the N-1 security criterion, and construct the corresponding Flow-Based domain. To rigorously isolate the impact of the methodology itself from variations in the input data, NTC values were recalculated using the same models as a bilateral maximum for each individual border. The results expose the structural limitations inherent in the NTC method: the sum of bilateral NTC export values for North Macedonia theoretically reaches 6,454 MW, whereas the maximum simultaneous capacity that can actually be achieved is only 1.921 MW, representing an overestimation of 70% (and 68% for imports). This discrepancy is not due to erroneously calculated individual values but stems from the fact that each bilateral value assumes that the remaining three borders are inactive conditions physically impossible to fulfill simultaneously. Since the power exiting North Macedonia channels through the same physical transit corridors regardless of destination, the total simultaneous export (1,921 MW) remains close to the capacity of the strongest single border (2,209 MW), confirming that multiple borders do not linearly translate to a multi-fold increase in capacity. Furthermore, the analysis indicates that in none of the 287 snapshots is capacity limited by normal operating conditions, but rather by the N-1 security criterion. Indicatively, in approximately every tenth hourly snapshot, a transmission line on the Kosovo–Albania border—over which the Macedonian operator lacks direct system visibility—acts as the limiting element. The available capacity exhibits highly dynamic behavior, fluctuating from 772 MW to 2,571 MW over the twelve-day period, proving the inadequacy of seasonally fixed values. The practical conclusion of this paper is that the successful implementation of the Flow-Based model in North Macedonia will critically depend on the selection of monitored elements, the definition of available remedial actions, and the operator's autonomous capability to perform this complex calculation.

THROUGH TRANSPARENCY TO GREATER COMPETITIVENESS IN CREDITATION AND FINANCING OF ENERGY INFRASTRUCTURE PROJECTS

Sasa Maksimovski, Anastasija Ilieska



The implementation of capital investment projects in the energy sector is a complex process that requires the provision of significant financial resources, quality project preparation, efficient risk management and the establishment of transparent and competitive decision-making mechanisms. Especially for electricity transmission system operators, such as AD MEPSO, investments have strategic importance for the security of the electricity system, energy stability and the fulfillment of national and European energy goals. This document elaborates the procedure for establishing a competitive and transparent process for providing financial resources for the implementation of capital projects through credit borrowing. The entire project cycle is presented, starting from the identification of the project need and preparation of the Project Concept, through the preparation of a feasibility study, economic and financial analysis and project documentation, to the selection of a financing model, implementation of the borrowing procedure, project implementation and its monitoring and evaluation. Special attention is paid to the application of the principles of transparency, competitiveness, economy and responsibility when selecting financial sources, as well as the need for a prior analysis of financial sustainability, credit capacity, borrowing risks and the ability to service credit obligations. The roles of the management bodies of AD MEPSO, the procedures for obtaining consents from the competent institutions and the requirements of financial institutions regarding the readiness of the project for implementation (Project Readiness) have also been developed. The document is aligned with the principles set out in the Regulation on Public Investment Management ("Official Gazette of the Republic of North Macedonia" No. 78 of 11.04.2025), the Law on Budgets, the relevant borrowing regulations, as well as with the good international practices of the European Investment Bank (EIB), the European Bank for Reconstruction and Development (EBRD) and the World Bank. The establishment of such a systematized procedure enables better preparation of capital projects, reduction of financial and project risks, increase of confidence among creditors and provision of long-term sustainable financing of strategic investments of AD MEPSO.

THE NEED TO ESTABLISH A SUSTAINABLE CORPORATE RISK MANAGEMENT MODEL IN AD MEPSO

Sasa Maksimovski, Anastasija Ilieska



In conditions of rapid technological change, energy transition, climate challenges, geopolitical uncertainties and increased cyber threats, corporate risk management in energy companies is one of the key functions of modern corporate governance. Institutions and companies that manage critical infrastructure have an obligation to establish an integrated system that enables timely identification, assessment, treatment and continuous monitoring of risks that may affect their operations, stability and sustainability. AD MEPSO, as the operator of the electricity transmission system of the Republic of North Macedonia, is a company of particular importance for the energy security of the country and the reliability of the regional electricity system. The Company's operations are exposed to various strategic, operational, financial, regulatory, cyber, reputational and compliance risks, which imposes the need to establish a comprehensive and sustainable corporate risk management system. The purpose of this paper is to highlight the need to establish a corporate risk management model through the Corporate Risk Management Policy, which is the basis of modern corporate governance and an integral part of the system of internal financial controls, integrity management and ensuring the secure and continuous functioning of the Company. The paper additionally analyzes the specific risks characteristic of electricity transmission system operators, as well as the significance of the compliance function, cybersecurity and integrity in establishing an integrated risk management system. Special attention is paid to the establishment and application of the Risk Register as a basic instrument for identifying, assessing, monitoring and treating risks, as well as the Map of Workplaces Susceptible to Corruption as a mechanism for recognizing and managing the risks of corruption and conflict of interest. The results show that the application of a single risk management methodology enables a systematic approach to the identification and assessment of risks, more efficient allocation of resources, timely decision-making, reduction of exposure to critical risks and improvement of the efficiency of corporate governance. The integration of risk management into the processes of strategic and operational planning contributes to a higher level of resilience, transparency, accountability and long-term sustainability of the Company.

Introduction of a Reactive Power Provision Mechanism through Grid Codes – The First Step towards Establishing a Market for Non-Frequency Ancillary Services in the Republic of North Macedonia

Igor Stojanovski, Zhivorad Serafimovski



Directive (EU) 2019/944 establishes a framework for the transparent, non-discriminatory and, where economically justified, market-based procurement of non-frequency ancillary services required for the secure operation of power systems. Within this framework, voltage control and reactive power provision play a particularly important role, as they represent fundamental prerequisites for the secure and stable operation of transmission networks under conditions of increasing integration of renewable energy sources. In accordance with the European regulatory framework, transmission system operators are required to establish appropriate mechanisms for the procurement of these services and to define the technical requirements for their provision. A previously developed concept for the procurement of non-frequency ancillary services identified three complementary mechanisms for reactive power procurement (Pillar A, Pillar B and Pillar C), which together form the basis for a functional framework for these services. Within this concept, Pillar A is based on technical requirements and obligations defined through grid codes, Pillar B on market-based procurement, and Pillar C on fully integrated network components. This paper focuses on the implementation of Pillar A within MEPSO as the first and necessary phase in establishing a national framework for non-frequent ancillary services. The analysis reviews the requirements of the European regulatory framework, relevant practices applied by European transmission system operators, and the possibilities for their implementation within the Macedonian power system. Particular attention is given to the definition of minimum technical capabilities for reactive power provision, the role of generation facilities and renewable energy sources, the conditions for service activation by the system operator, and potential remuneration mechanisms. The results indicate that the implementation of Pillar A represents a technically sound and regulatorily justified approach for securing the required sources of reactive power, while simultaneously creating the prerequisites for the development of future market-based procurement mechanisms for non-frequency ancillary services. Such an approach enables a gradual transition from the existing framework towards modern European practice, providing enhanced voltage stability, more efficient utilization of available resources, and compliance with European energy legislation.

Application of Machine Learning in SCADA Systems for Power System Infrastructure

Ivona Josifoska, Andrea Zlatkov, Violeta Ingilizova Miovska, Stefan Spasovski

SCADA systems are the foundation for monitoring, control, and automation of power system infrastructure, generating large volumes of real-time operational data. The rapid development of machine learning has created new opportunities for analyzing these data, improving operational efficiency, and supporting decision-making processes. This paper examines the application of machine learning in SCADA systems, with a focus on load forecasting, anomaly detection, predictive maintenance, and optimization of power system operation. In addition, the paper discusses the main benefits and challenges associated with the implementation of machine learning algorithms in modern SCADA systems.

Cybersecurity Risk Analysis and Protection Mechanisms for SCADA Systems in Power System Infrastructure

Ivona Josifoska, Andrea Zlatkov, Violeta Ingilizova Miovska, Stefan Spasovski, Ivana Petrusevikj

The power system infrastructure is a critical component of modern society, where Supervisory Control and Data Acquisition (SCADA) systems play a key role in monitoring, controlling, and automating the generation, transmission, and distribution of electrical energy. With the increasing digitalization and connectivity of industrial control systems, their exposure to cyber threats has significantly increased. This paper analyzes the main cybersecurity risks affecting SCADA systems in power system infrastructure, including unauthorized access, malware, attacks on industrial communication protocols, and denial-of-service attacks. Furthermore, it examines modern protection mechanisms such as network segmentation, access control, intrusion detection systems, and the implementation of international cybersecurity standards. The aim of this paper is to emphasize the importance of a comprehensive cybersecurity approach in ensuring the secure, reliability, and continuous operation of SCADA systems within the power sector.



Disaster Recovery Location

Aleksandar Nikolovski

Modern power systems are increasingly dependent on information and communication technologies (ICT), which provide support for business processes, system management and the exchange of critical information. As the Transmission System Operator, MEPSO is responsible for ensuring high availability, reliability and continuity of the ICT infrastructure supporting its critical operations.
With the aim of enhancing resilience to various types of risks, including technical failures, natural disasters, physical incidents and cyber threats, a project has been implemented for the construction of a new Disaster Recovery (DR) site equipped with modern server infrastructure.
The project includes the construction of a new server room with a capacity of six IT racks, redundant power supply and cooling systems, communication infrastructure, automated management systems, fire protection and physical security systems.
The implemented solution provides a foundation for ensuring the continuity of ICT services and strengthening the cyber resilience of critical energy infrastructure..

Can Artificial Intelligence replace the electric power system operators?

Dimitar Iliev

Abstract. The rapid development of Artificial Intelligence (AI) is creating new opportunities to enhance power system operation through automation, advanced data analytics, and intelligent decision support. Modern AI algorithms enable more accurate load and renewable generation forecasting, early fault detection, and optimization of power system performance. Despite these technological advances, the complete replacement of power system operators remains unlikely due to the need for human judgment, experience, and accountability during emergencies and unforeseen operating conditions. This paper will examine the opportunities and limitations of AI applications in power system control centers and discuss the evolving role of system operators in an increasingly automated electric power industry.



Application of Remedial Actions in the Real-Time Operation of the Macedonian Power System

Zlatko Acevski, Filip Todoroski



The stable operation of the power system is fundamental to ensuring the continuous and reliable transmission of electrical energy to consumers connected to the transmission network. Real-time power system operation is frequently accompanied by transmission line and equipment overloads, voltage levels outside the permissible operating limits, the need for changes in network topology to alleviate congestion, and other operational constraints. To ensure the secure and reliable operation of the power system, the on-duty dispatchers at the National Dispatch Centre of MEPSO apply a wide range of preventive and remedial actions. This paper presents an analysis of selected real-time power system operation scenarios and the application of appropriate remedial actions aimed at restoring the power system to its normal operating state.

Reconstruction of command control buildings to improve energy efficiency, integrate renewable energy sources and reduce CO2 emissions

Sladjana Koljozov. Petrit Latifi, Semijal Ziberi



AD MEPSO is implementing a project to reconstruct control buildings at several Substations, aiming to improve energy efficiency. In addition to enhancing the functionality of the buildings, the project will contribute to reducing electricity consumption, integrating renewable energy sources, and lowering CO_2 emissions. The work on the control buildings includes construction, electrical, and mechanical tasks, new systems installations, improvements to thermal insulation, and the modernization of heating, cooling, and lighting systems. A particularly significant aspect of the project is the installation of photovoltaic systems with a capacity of 40 kWp on certain facilities. This will enable a portion of the required electricity to be supplied from renewable sources, further contributing to greater energy independence and more sustainable facility operations.

Cybersecurity by Design for Smart Grids

Enis Drndar, marina Nedanovska Donovska

The digital transformation of power systems is fundamentally reshaping modern smart grids while simultaneously increasing their exposure to cyber-attacks. This paper analyzes the cybersecurity challenges arising from the digitalization of power grids, with particular emphasis on the gradual convergence of traditionally isolated operational technology (OT) and information technology (IT) environments. The paper examines the need for cybersecurity to become a fundamental principle in the development of digitalized energy systems through the adoption of the "Cybersecurity by Design" concept, which enables the integration of cybersecurity requirements from the earliest stages of the system lifecycle. The analysis is presented within the context of the NIS2 Directive and relevant national cybersecurity rules for critical energy infrastructure, emphasizing risk management, the integration of cybersecurity into corporate governance, and operational resilience. The paper concludes that adopting a "Cybersecurity by Design" approach is essential for ensuring resilience, long-term reliability, and trustworthiness in the operation of smart grids.

The Impact of CBAM on the Energy Sector and Industry in North Macedonia: Challenges and Opportunities for Decarbonization

Borko Aleksoski, Romeo Josifoski



The European Union's Carbon Border Adjustment Mechanism (CBAM) has introduced fundamental changes to cross-border trade, imposing financial obligations based on the embedded greenhouse gas emissions of certain industrial and energy products. This paper analyses the impact of CBAM on export-oriented sectors in North Macedonia. It also examines the risks of losing competitiveness on the European market, as well as the need to establish a national monitoring, reporting, verification and accreditation (MRVA) system for emissions. In addition, the paper elaborates

on strategic options for compliance with EU regulations, including the introduction of an emissions trading system that is in line with the EU ETS, as well as the transformation of the domestic energy mix towards renewable energy sources and the introduction of national carbon taxes, which would retain significant financial resources in the domestic budget.
The aim is to offer concrete recommendations for accelerated decarbonization and adaptation of the Macedonian economy to new market conditions.



Registration of solar power plant in the balancing energy market

Biljana Zafirova Naumova, Milena Kraleva



Согласно In accordance with the amendments to the Energy Law and the Balancing Rules, solar power plants are now eligible to participate in the balancing energy market as Balancing Service Providers (BSPs). Solar power plants may be registered as Balancing Service Provider (BSP), thereby becoming eligible to provide balancing services for the needs of the Transmission System Operator (TSO). This paper describes the process of registration, testing, and integration of the solar power plant MEY ENERGY DOO Skopje, operating within the balancing entity SPP Novaci, into the balancing energy market. Through the presentation of the practical implementation of the legal and



technical requirements, the paper analyzes the steps necessary for the successful participation of solar power plants as Balancing Service Providers.

Commercial Valorization of the OPGW Optical Infrastructure of JSC MEPSO – Opportunities for the Development of Electronic Communications Networks and New Revenue Streams

Robert Ordanoski



The growing demand for high-capacity and secure communication infrastructure creates new opportunities for transmission system operators to maximize the value of their existing optical assets. This paper analyzes the commercial potential of the OPGW optical fiber infrastructure deployed along the transmission network of JSC MEPSO. The study examines the technical, economic, and regulatory aspects of leasing dark fiber and providing wholesale telecommunications infrastructure to mobile network operators, Internet service providers, public institutions, and enterprise customers. The analysis demonstrates that the existing optical network can generate sustainable additional revenue while supporting broadband expansion, 5G backhaul, Smart Grid applications, cloud connectivity, and national digital resilience. Furthermore, the paper proposes commercialization models and strategic recommendations aimed at improving infrastructure utilization, strengthening MEPSO's market position, and contributing to the digital transformation of Republic of Macedonia.

Technical solution for the newly installed supervisory and control equipment in Resen, Delcevo and Strumica 1 substations

Mia Buralieva, Marjan Janevski



This paper presents the main characteristics of the technical solution implemented through the newly installed Supervisory and Control equipment at the Resen, Delchevo and Strumica 1 substations, as well as the specific features and experience gained from its recent commissioning. Specifically, the project involved the modernization and adaptation of the substations by installing new supervisory and control equipment. The main challenge was to meet all modern requirements for remote supervision and control systems in substations with very limited available space. The supervision and control systems of the substations are based on Remote Terminal Unit (RTU) devices for supervisory and control, together with Local Control Panels (LCPs) for all bays. An important benefit of these projects is the complete segregation of the equipment owned by MEPSO JSC and EVN Macedonia.

Modern Protection Schemes for 300 MVA Power Transformers

Liridon Lutfiu, Artan Ramani



Power transformers rated at 300 MVA are among the most critical assets in modern 400/110 kV transmission networks, where their reliable operation directly affects system security, power quality, and network availability. Due to their high replacement cost, long manufacturing lead times, and strategic importance, transformer protection has evolved significantly from conventional electromechanical relays to intelligent digital protection systems integrated with real-time monitoring technologies. This paper presents an overview of modern protection schemes applied to large power transformers, emphasizing both traditional protection principles and recent technological advancements. The study reviews essential protection functions, including percentage differential protection (87T), restricted earth fault (REF), overcurrent and earth fault protection (50/51), Buchholz relay (63), sudden pressure protection, overfluxing protection (24), thermal overload protection (49), and overvoltage protection (59). Furthermore, the paper discusses the integration of IEC 61850-based Intelligent Electronic Devices (IEDs), process bus communication, SCADA systems for faster fault detection, improved selectivity, and enhanced operational reliability. In addition, the paper highlights the growing role of condition-based protection, incorporating online dissolved gas analysis (DGA), partial discharge monitoring, bushing condition assessment, oil temperature supervision, and transformer health index evaluation. These technologies enable predictive maintenance strategies that reduce unplanned outages and extend transformer service life. Finally, the paper addresses current challenges associated with renewable energy integration, increasing network loading, cybersecurity of digital substations, and future trends in transformer protection. The implementation of advanced digital protection schemes combined with continuous condition monitoring significantly improves the reliability, availability, and operational security of high-voltage transmission systems while minimizing maintenance costs and reducing the risk of catastrophic transformer failures.

The impact of the 15 minute market time unit on power system balancing in systems with high renewable energy integration

Svetlana Pavleska Mladenovikj

The rapid expansion of renewable energy sources increases variability in power systems and emphasizes the importance of greater time granularity for more efficient balancing. This paper analyzes the difference in imbalances created by electricity market participants when using 60 minute and 15-minute trading intervals. It compares the magnitude of imbalances, the dynamics of deviations, and their financial implications in both MTUs. The results show that the 15-minute MTU enables faster detection and correction of deviations, more accurate price signals, and more frequent updates of intraday schedules, leading to reduced imbalances and a lower need for system reserves. The introduction of 15-minute products is required under Regulation (EU) 2019/943 and represents a key step toward harmonizing with the European electricity market and improving system stability.

Optimizing the operation of a photovoltaic system using a battery storage system

Nikola Pangovski



Овој This paper analyzes the application of arbitrage in a photovoltaic system with integrated battery electricity storage systems (BESS), simulating the operation under market conditions. Using real historical market data from the PDO of MEMO DOOEL Skopje for the period 2025 and 2026, different operating scenarios, economic feasibility and the impact of key technical parameters, such as battery capacity, efficiency and operational constraints, are considered. Special emphasis is placed on short-term trading horizons (day-ahead and intraday markets), where arbitrage opportunities are most pronounced and the greatest financial result can currently be achieved.

Energy efficiency of control buildings in 110 kV HV substations – Veles and Bitola 11

Vlatko Galabov, Blerta Jonuzi, Selvije Ramani, Dejancho



The control buildings in SS Veles and SS Bitola 1 represent a significant share of electricity consumption, particularly for heating, cooling, and lighting. The analysis indicates considerable heat losses due to insufficient insulation, inefficient systems, and inadequate windows. Based on the recommendations from the conducted energy audits, the proposed activities include adaptation and reconstruction of the buildings, encompassing facade and roof insulation, window replacement, installation of LED lighting, and implementation of energy-efficient heating and cooling systems. These measures are expected to reduce energy consumption and improve the energy performance class in accordance with national standards.

Reactive power control

Despina Sokolova, Elena Ackoska, Stefanija Simovska



With the increasing share of photovoltaic power plants in the power system, their role is expanding beyond active power generation to the provision of ancillary services, particularly voltage regulation and reactive power management. This paper presents the results of testing the Q-Night Mode operation of inverters at the Oslomej 3A, Oslomej 3B, and Novaci photovoltaic power plants, as well as the capability of TE-TO Skopje to provide reactive power support through under excited operation. Measurements show that Q-Night Mode compensates reactive power generated by connection cables and enables additional reactive power absorption from the grid. Analyses, simulations, and field tests confirm improved voltage conditions and effective reactive power support for the transmission network.

Electric Vehicles and Grid Transformation: Technical, Operational and Regulatory Challenges for the Macedonian Power System

Blagoj Koteski

Electric mobility introduces a new category of dynamic electricity demand with direct impact on distribution and transmission networks. This paper analyses the technical, operational and regulatory challenges of integrating electric vehicles into the Macedonian power system, focusing on charging infrastructure, grid capacity, peak demand, voltage quality, balancing and coordinated planning. The research is based on international EV reports, national strategic documents, existing studies on plug-in electric vehicles and the current legal and regulatory framework in North Macedonia. The analysis indicates that unmanaged charging may create local overload, increase peak demand and require additional grid investments. With smart charging, dynamic tariffs, aggregation and storage, electric vehicles can become an important flexibility resource for a more stable and sustainable power system.

Cybersecurity of relay protection systems in the conditions of digitalized substations

Zoranco Mitev, Toni Atanasov, Goran Dimitrievski



The digitalization of power systems and the replacement of electromechanical with numerical relay protection has brought significant technological benefits, while simultaneously exposing protection systems to new cyber threats. The increased connectivity of intelligent electronic devices (IEDs) through standardized communication protocols, primarily IEC 61850, creates a new dimension of risk for power system stability. This paper presents an updated analysis of threats, the regulatory framework, and modern approaches to protection of relay protection systems, with particular emphasis on ENTSO-E requirements and European regulations.

Three decades of experience from the application of numerical relay protection in the Macedonian transmission system

Zoranco Mitev, Stefce Stefanovski, Aleksandar Atanasovski, Martina Bogdanovska



The implementation process of numerical relay protection in the Macedonian power transmission network began in 1998 and represents one of the most significant processes of technological modernization of protection systems. Almost three decades of operational experience allows an objective assessment of the benefits and challenges brought by this technology. The paper presents practical experiences from the implementation and exploitation of numerical protection, the acquired benefits in terms of functionality, sensitivity and availability of information, as well as new challenges related to communications, software, cybersecurity and the need for continuous education of personnel.

Historical changes to the EMFIP Configuration Matrix, New Data Item Monitoring (DIM) and MEPSO compliance with the latest changes in data submission to the ENTSO Transparency Platform (EMFIP)

Dionis Tanaskoski, Daniela Gavriloska, Jovica Sazdovski



AD MEPSO has reached a high level of technical and legal compliance through the modernization of the MMS (Market Management System) platform (XML Standards, Modularity), adaptation to the new Manual of Procedures (File Size Control, Market Resolution), Harmonized Allocation Rules (HAR) and integration into JAO (Joint Allocation Office). New Data Monitoring System (DIM) for insight into the completeness of data submitted to TP. The new DIM solves previous problems with monitoring real generation per GU and is more precise and reliable in the insight into the completeness of data submitted to TP, which leads to increased operational flexibility, improved return on investment, reduced dependence on development releases and faster communication with end users.

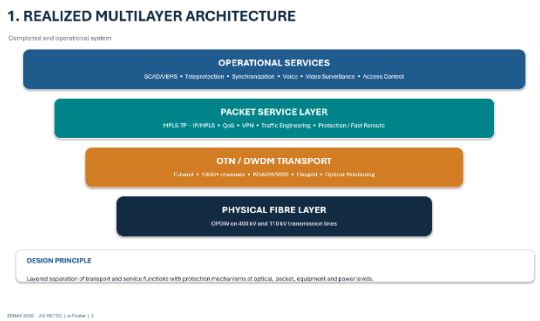
National Resource Adequacy Assessment

Sime Kuzarevski

Resource adequacy is defined as the ability of a power system to reliably meet demand under uncertainty in load and generation availability. This paper presents a national resource adequacy assessment following ERAA methodology of ENTSO-E, based on Monte Carlo simulation using Antares Market Simulator. The modelling framework explicitly represents variable renewable generation, thermal availability, demand uncertainty, and cross-border interconnections. Reliability is quantified using two indicators, Loss of Load Expectation (LOLE) and Expected Energy Not Served (EENS), across a range of future system conditions. The results provide a probabilistic assessment of supply security under increasing renewable penetration and variability, supporting adequacy analysis within the European framework and identifying key system drivers in transition pathways.

IT systems and applications in electrical power facilities

Jasmina Kecap, Tomi Bozinovski



Reliable and secure telecommunications infrastructure is a fundamental requirement for transmission system operators to ensure real-time operation, monitoring, and protection of the power system. This paper presents a carrier-grade telecommunications backbone based on a layered architecture comprising an Optical Transport Network (OTN/DWDM) transport layer and an IP/MPLS packet-based service layer deployed over OPGW fiber infrastructure. The solution enables deterministic, low-latency, and high-availability communication for critical applications, including SCADA/EMS, teleprotection, synchrophasor data exchange, and operational voice services. The architecture incorporates redundancy, traffic prioritization, and end-to-end network management through an integrated Network Management System (NMS), supported by advanced cybersecurity mechanisms in line with IEC 62351 principles. Such infrastructure is essential for transmission system operators to ensure resilient, efficient, and secure transport of operational data, enabling stable grid operation and integration within regional electricity markets..



JOINT EUROPEAN RESEARCH AND DIGITAL TWIN DEMONSTRATIONS

At ENERGETIKA 2026, researchers from the University of Innsbruck (UIBK), Austria, and AD MEPSO, North Macedonia, presented three joint contributions demonstrating a practical engineering for energy-system Digital Twins: creating system models with generative AI, deploying operational Digital Twins in the cloud, and federating independently deployed twins for coordinated operation. Each contribution was authored by three researchers from UIBK and three from MEPSO.

01 GenDT-Demo	02 CloudDT-Demo	03 FedDT-Demo
DESCRIBE → MODEL	MODEL → DEPLOY	CONNECT → COORDINATE

JOINT TECHNOLOGY DEMONSTRATION · STAGE 01

01 GenDT-Demo

From Energy-System Architecture to Digital Twins with Generative AI

Natural-language engineering of hierarchical energy-system models

AUTHORS: *Marco Cotrotzo, Sashko Ristov, Yevhenii Bodanov (UIBK); Sime Kuzareski, Kliment Naumoski, Aleksandar Paunoski (AD MEPSO).*

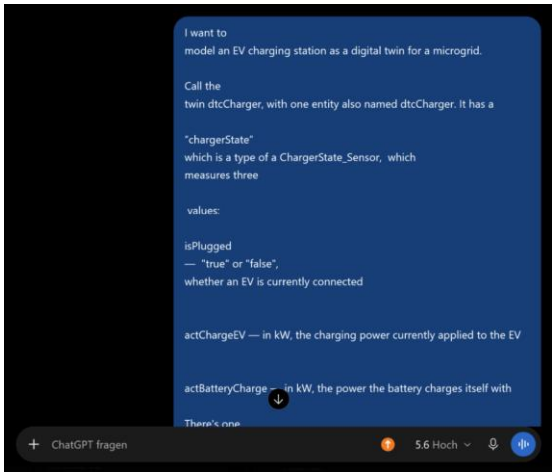
The demonstration shows how domain experts can describe an energy system in natural language and obtain a structured Digital Twin model in SysML v2. A hierarchical representation captures the overall system, its entities and components, and the corresponding measurement and configuration information. For a microgrid, this may include photovoltaic generation, stationary battery storage, and electric-vehicle charging infrastructure.

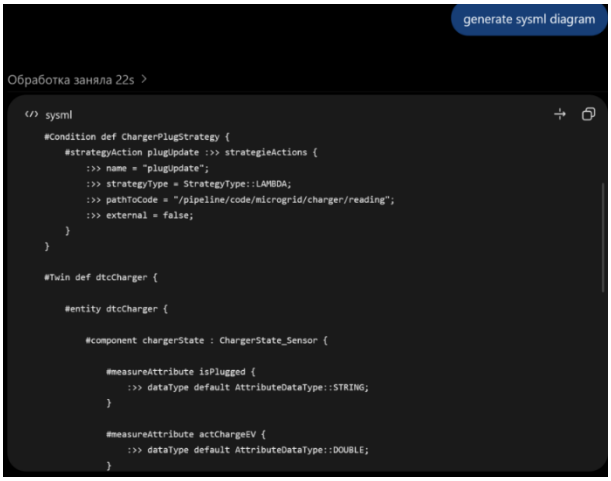
The engineer can then request changes in the same manner. For example, adding a charger, modifying a component, or combining separately developed Digital Twin models into a larger system. This reduces the amount of manual modelling needed to keep Digital Twin descriptions aligned with evolving energy-system architectures.

European project connection | MATISSE

The demonstrated modelling approach builds on digital-engineering research developed within MATISSE.

DEMONSTRATION FIGURES





JOINT TECHNOLOGY DEMONSTRATION · STAGE 02

02 CloudDT-Demo

From Energy-System Models to Operational Cloud Digital Twins: A Containerized Deployment Pipeline

Turning a formal engineering model into a running cloud-based Digital Twin

AUTHORS: *Yevhenii Bodanov, Marco Cotrotzo, Sashko Ristov (University of Innsbruck); Sime Kuzareski, Kliment Naumoski, Aleksandar Paunoski (AD MEPSO).*

The second demonstration continues from formal energy-system models and shows how they can be transformed into operational Digital Twins. Its containerized deployment pipeline accepts a model from SysML v2 and performs the processing and cloud configuration required to instantiate the corresponding Digital Twin infrastructure.

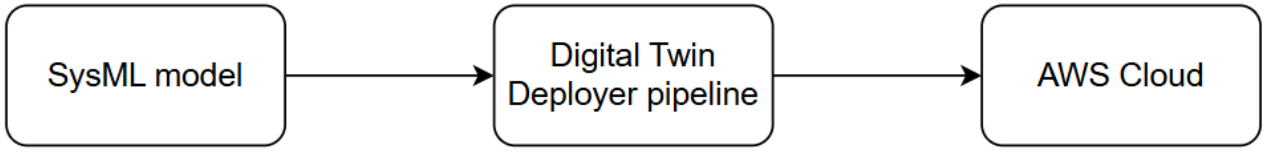
The running environment includes representations of the energy assets, device and sensor connectivity, cloud-side processing and data services, and a Grafana monitoring interface.

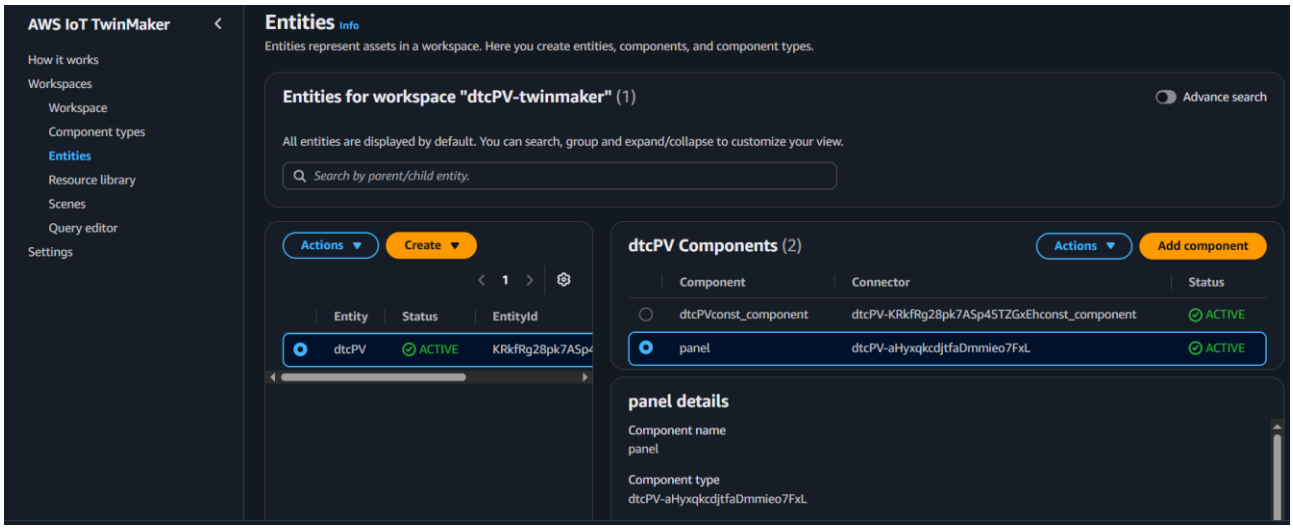
In the presented microgrid example, photovoltaic generation, battery storage, and EV charging are represented in a cloud Digital Twin. Once deployed, sensor values can be supplied to the twin and inspected through Grafana. The demonstration highlights a practical transition from the engineering description to a functioning software environment without manual configuration of each cloud resource.

European project connection | MATISSE

This demonstration transfers a MATISSE development outcome to a broader energy-sector audience through the joint UIBK–MEPSO conference contribution. It complements the model-creation stage and prepares the infrastructure used in subsequent monitoring, control, and federation scenarios.

DEMONSTRATION FIGURE





JOINT TECHNOLOGY DEMONSTRATION · STAGE 03

03 FedDT-Demo

From Independent Digital Twins to Coordinated Energy Systems: Federation and Emulation in Practice

Coordinating distributed assets and testing TSO–aggregator interactions

AUTHORS: *Sashko Ristov, Yevhenii Bodanov, Marco Cotrotzo (University of Innsbruck); Sime Kuzareski, Kliment Naumoski, Aleksandar Paunoski (AD MEPSO).*

The third demonstration connects independently deployed cloud Digital Twins through selected data exchanges and lightweight cloud functions. Each twin retains its own representation and interfaces, while the federation combines information needed for coordinated control. Model-consistent emulators supply measurements, enabling tests even when the corresponding physical assets are not fully available.

The local example coordinates photovoltaic generation, battery storage, EV charging, and grid conditions. A second scenario, developed together with MEPSO, extends the concept to communication between a transmission-system/grid twin and an aggregator-side federation of flexible resources. Representative conditions include high voltage during low-consumption periods and balancing-service activation through aFRR/mFRR.

European project connection | FLEXI

MEPSO contributes to FLEXI through its Advisory Board and by defining operationally relevant TSO–aggregator coordination scenarios. The demonstration illustrates an executable basis for investigating aggregated flexibility and future energy-system services.

DEMONSTRATION FIGURE



A FOUNDATION FOR THE NEXT JOINT PROJECTS

The three demonstrations represent complementary building blocks (model creation, cloud deployment, and coordinated operation) that can support further joint research. The University of Innsbruck also coordinates the upcoming European projects twinRE and TwinD, both involving MEPSO as a partner. twinRE advances renewable-energy Digital Twins, forecasting, and orchestration; TwinD investigates Digital Twin technologies for wind-energy reliability, condition monitoring, and operation and maintenance. The ENERGETIKA contributions provide a useful starting point for continued collaboration, without implying that the demonstrations are results of these new projects.


ЗЕМАК
ЗА ОДРЖЛИВА ИДНИНА
МЕЃУНАРОДНА КОНФЕРЕНЦИЈА ЕНЕРГЕТИКА 2026
INTERNATIONAL CONFERENCE ENERGETICS 2026
2. РЕЛЕЈНИ УРЕДИ И АРХИТЕКТУРА
Интелигентни електронски уреди (IED)
Заштита, мониторинг, снимање на грешки, далечинско управување
Секој нов поврзан уред е нова потенцијална точка на напад
Лозинките сами по себе не се доволни против APT закани
Комуникациска структура на пристап
Сертифициран корисник
Мрежа со селективен пристап
Рутер Layer 2 / Layer 3
Уред за релејна заштита
Layer 2 — сегментација преку VLAN
Layer 3 — IP рутирање со контрола на пристап (ACL)
Кратенки
IED — Intelligent Electronic Device (интелигентен електронски уред)
APT — Advanced Persistent Threat (напредна постојана закана)
VLAN / ACL — Virtual Local Area Network / Access Control List
МЕПСО

МЕПСО ЗЕМАК