Electrical Engineering
Annual International Congress

Proceeding of Annual International Congress on

Electrical Engineering

May 8-9, 2025 Oxford, United Kingdom

Electrical Engineering Research Training Center

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Annual International Congress

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Table Content:

Electrical Engineering
Annual International Congress

Annual International Congress on Electrical Engineering

May 8-9, 2025
Oxford, United Kingdom

Ship predictive control system design based on the vessel digital twin

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Abstract

Model Predictive Control (MPC) is predicated on a model-based approach, thus necessitating the development of an internal predictive model that is both reliable and realistic. It is not feasible to carry out this identification process on a real ship, due to the trials number and duration of each experiment, which are affected by the environmental disturbances that cannot be eliminated. Consequently, there is an imperative to identify a methodology for generating input-output data sets for the purpose of predictive model identification and validation. This paper details the development of a digital twin of a training ship, utilizing the mathematical model of the MMG (Mathematical Model Group). Following validation, the digital twin is employed as a source of input-output data for the model identification process. The paper goes on to describe the design of a ship predictive control system, starting from the initial idea and considering requirements, modelling and prediction, control signals computation, simulations and hardware-in-the-loop tests. The entirety of the research is grounded in the utilization of the Matlab software. The digital twin operates in real time as a component of the hardware-in-the-loop system, thereby addressing a current research gap and enhancing the potential for enhancing the control quality in autonomous shipping predictive systems.

Keywords: Predictive Control; MPC; digital twin; autonomous vessel

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Annual International Congress on Electrical Engineering

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Enhanced Efficiency and Stability in Dye-Sensitized Solar Cells Using PtNP-Doped PANI/g-CN Nanocomposites: A Promising Alternative to Traditional Platinum Electrodes

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Abstract

This study explores the development and application of Pt nanoparticle (PtNP)-doped polyaniline (PANI) and graphitic carbon nitride (g-CN) nanocomposite-based counter electrodes for dye-sensitized solar cells (DSSCs). The goal was to improve the efficiency, stability, and cost-effectiveness of DSSCs by using these nanocomposites as alternatives to traditional platinum (Pt) counter electrodes.

DSSCs with PtNP/PANI/g-CN counter electrodes demonstrated impressive initial performance, achieving an open-circuit voltage (V_{OC}) of 720 mV, a current density (J_{SC}) of 22 mA/cm², and a power conversion efficiency (PCE) of 10,05%. By comparison, traditional Pt-based DSSCs began with similar values, recording a V_{OC} of 720 mV, J_{SC} of 19 mA/cm², and a PCE of 9.14%. However, what truly sets the PtNP/PANI/g-CN electrodes apart is their remarkable stability. Long-term stability tests, carried out weekly and monthly over 12 months, showed that these cells retained 80% of their original efficiency, maintaining a V_{OC} of 708 mV, J_{SC} of 17 mA/cm², and a PCE of 7.98%. In stark contrast, DSSCs using traditional Pt electrodes experienced a significant decline, with their final V_{OC} dropping to 583 mV, J_{SC} to 12 mA/cm², and PCE to just 4.32%. This highlights the superior longevity and performance retention of the PtNP/PANI/g-CN nanocomposite electrodes.

To evaluate long-term stability, weekly and monthly electrochemical impedance spectroscopy (EIS) measurements were performed over a 12-month period. The obtained Nyquist plots indicated that the PtNP/PANI/g-CN electrodes exhibited lower series resistance compared to conventional Pt electrodes, with a smaller semicircle diameter, demonstrating superior charge transfer properties.

The comparative analysis highlights that PtNP/PANI/g-CN-based DSSCs outperformed those with traditional Pt electrodes, both in terms of initial efficiency and long-term stability. PtNP/PANI/g-CN nanocomposites not only offer a more economical solution but also ensure higher electrochemical performance and durability, making them a promising alternative for future DSSC technology.

Keywords: DSSC; Renewable Energy Systems; Solar cells; PtNP/PANI/g-CN nanocomposite; Counter electrode

Electrical Engineering
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Fault Tolerant Control Using a Novel Cascade Controller Based on Stochastic Control and Signal Output Regulation Control for Collaborative Subsystems

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Abstract

Fault-tolerant control to overcome the effects of the fault in the collaborative subsystems is vital in modern industries. We can enhance system reliability by leveraging observers to detect and diagnose faults based on their specific types. Controllers must respond to these diagnosed faults and be reconfigured to effectively meet control objectives. This paper presents an innovative controller that combines two methodologies: signal output regulation control and stochastic control. The stochastic component is grounded in B-spline functions, while the signal regulation aspect focuses on optimizing output signals by pole placement. This cutting-edge controller has been successfully implemented in fault-tolerant control, where two collaborative subsystems have been demonstrated. The first subsystem, impacted by an additive fault, uses an optimal observer for diagnosis, while the second subsystem employs an observer specifically designed to identify actuator faults. Adopting this approach can significantly elevate the resilience and performance of industrial systems. As a result of comparing the objective function, the new controllers are more reliable than the signal output regulation, and the performance overall is enhanced.

Keywords: Fault Tolerant Control FTC; Stochastic Control S; Signal Output Regulation Control SRC; Additive Fault Observer AFO; Actuator Fault Observer ACFO.

Electrical Engineering
Annual International Congress

Annual International Congress on Electrical Engineering

May 8-9, 2025
Oxford, United Kingdom

RESULTS OF COMPARATIVE LABORATORY TESTS OF HYDRAULIC RAM PUMPING UNITS

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Abstract

The article is aimed at increasing the efficiency of pasture water supply and irrigation of land plots of peasants and farms of the agro-industrial complex by improving the hydraulic ram pumping installation for lifting water from watercourses. Design and technological diagrams of two new standard sizes of hydraulic ram pumping units developed at Kazakh National Agrarian Research University for lifting water from watercourses for watering pastures and irrigating land plots are given, their distinctive features, novelty, brief design, principle of operation, which, compared to analogues, have advantages in improving energy performance. Comparative results of laboratory tests of the developed standard sizes of hydraulic ram pumping units are given and the advantage of the improved standard size is proven. The authors proposed a design and technological scheme of a hydraulic ram pumping unit. A graph of the results of laboratory tests of two standard sizes of a hydraulically driven pumping unit in accordance with pressure dependencies has been obtained. As a result of the performed analyses and research work, various variants of the standard size of hydraulic ram pumping units have been developed, which have high reliability and convenience and ease of maintenance, increased energy performance.

The scheme of the hydraulic ram pumping unit developed by the authors makes it possible to increase the efficiency of the organization of water supply and thereby save fuel and energy resources. With the help of laboratory tests on a test bench, a comparative analysis of the main parameters of the performance indicators of the developed standard sizes of hydraulic ram pumping units was performed.

Keywords: Hydroram pumping unit, standard size, improved, watercourse, pasture watering, irrigation, laboratory testing, comparison, advantage

Electrical Engineering
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Oxford, United Kingdom

Contribution to the Optimisation of Grounding Resistances in Electrical Networks for Effective Lightning Protection

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Abstract

This research work deals with the optimisation of the resistances of grounding systems in electrical networks to protect them against lightning. In the face of increasing electrical disturbances, the study set out to assess the effectiveness of adjusting the distance between grounding electrodes in optimising the resistances of these systems. Simulations on the Djiri-Ngo line of the Congolese network show that, as well as increasing the number of electrodes, varying their distance also helps to reduce overall resistance. The results also show that each type of soil requires a specific configuration to achieve optimum resistance. This research highlights the importance of adapting earthing systems to local geological conditions in order to improve the safety of electrical infrastructures.

Keywords: Grounding electrode; Grounding resistance; Grounding system; Lightning protection; Optimisation

Electrical Engineering
Annual International Congress

Annual International Congress on Electrical Engineering

May 8-9, 2025
Oxford, United Kingdom

Land and aquatic spectral signatures analysis over a spatio-temporal hazardous area acquired by Worldview satellite

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Abstract

The land and aquatic spectral signatures have been estimated over a spatio-temporal video acquired by the NASA Worldview sensors. The high-resolution remote sensing frames have been recently collected on a hazardous area at the period of February to March 2025. In Figure 1-2, a hazardous area, a cyclone, is clearly presented.

The main objectives to be presented are:

1. Specifying and analyzing the land and the aquatic spectral signatures according to the days of acquisition.

2. Processing the data to segment the hazardous areas.

3. Assessing the processed images quantitatively and qualitatively.

Keywords: Spectral Signatures, Remote Sensing, Hazard Segmentation, Cyclone Monitoring

Electrical Engineering
Annual International Congress

Annual International Congress on Electrical Engineering

May 8-9, 2025
Oxford, United Kingdom

Ship's Mechatronic Electrohydraulic Steering Actuator with "Transvector" Control System

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Abstract

Ship's active maneuvering is carried out by the electrohydraulic (EH) drive of the steering gear located on the keel. The maneuvering properties of the object (which includes: hull, rudder, propeller) completely depend on the proper operation of the drive control system. To move the rudder blade, it is necessary to regulate the change of oil flow from the pump to the steering gear, which is carried out by a special controlling device - a servomechanism. In order to obtain structural stability in the controlled and automatic modes of operation, feedback is provided by the servomotor, not by the steering gear, which in most cases is a short-circuited rotor motor.

The main problem in creating an automatic control system/mechatronic system is the optimization of its structure and parameters taking into account certain criteria of the system components.

The development of automated electrical equipment, in particular frequency control drives, allows us to control the current coordination of an alternating current/induction motor machines. It is possible to provide the regulation accuracy and energy efficiency by means of the control system "transvector" which is necessary for controlling the ship's steering drives.

The article represents the discussion about the effectiveness of using the "transvector" control system for a short-circuited rotor motor, and as a result it is possible to provide the ship's steering mechatronic system with precise steering in the shortest possible time, which will minimize the ship's deviation from the course.

Keywords: Mechatronic Electrohydraulic system, ship steering gear, vector control system

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The Application of IoT for Real-Time Failure Detection and Prediction in 3D Printing: Towards Sustainable Production

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Abstract

The integration of the Internet of Things (IoT) with 3D printing technology presents a transformative approach to enhancing production efficiency and sustainability through real-time failure detection and prediction. This study explores how IoT-enabled sensors and data analytics can monitor critical parameters such as temperature, humidity, nozzle movement, and extrusion rates to identify defects and forecast potential failures during the printing process. By leveraging ICT technology and cloud-based analytics, IoT systems facilitate proactive interventions, reducing material waste, energy consumption, and production downtime. The approach aligns with sustainable manufacturing goals by optimizing resource usage and extending equipment lifespan. This paper highlights case study and framework demonstrating the potential of IoT to enable smarter, more resilient 3D printing workflows, offering insights for industrial adoption and further research in sustainable additive manufacturing within Industry 4.0.

Keywords: 3d printing, Industry 4.0, IoT, Mechatronics, Sustainability

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Annual International Congress on Electrical Engineering

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Oxford, United Kingdom

Jet Milling Process Control

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Abstract

Fine grinding of bulk materials in a jet mill is a high-energy process, so increasing the grinding efficiency, included increasing the productivity of the process and product quality while reducing energy consumption, is an urgent task. Two control directions have been developed for increasing the efficiency of the grinding process - gas-dynamic control and control by acoustic signals of working areas.

The control of gas-dynamic flows included the annular supply of an additional gas flow and the organization of a conical nozzle at the outlet of the acceleration tube that ensures the alignment of the vortex flow and a stable wall layer throughout the acceleration tube. These changes reduce the wear of the acceleration tube surface by abrasive materials, improve the quality (purity) of the product and increase the efficiency of grinding in counter-flows.

A new method of automatic control of the productivity of a jet mill using acoustic signals of the grinding zone has been created. It consists in controlling the mill loading and the quality of the grinding products under conditions of changing process modes and raw material size, which allows maintaining the highest process efficiency. Algorithms of the automatic mill loading control system, software and hardware for its implementation have been developed.

Keywords: Jet mill, Fine grinding, Energy efficiency, Gas-dynamic control, Acoustic signal monitoring

Electrical Engineering
Annual International Congress

Annual International Congress on Electrical Engineering

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Oxford, United Kingdom

ASYNCHRONOUS ELECTRIC DRIVE WITH REACTIVE POWER CONTROL

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Abstract

A method of controlling an asynchronous electric drive based on measuring and regulating the reactive power of an induction motor is proposed. The independence of the rotor flux and the electromechanical moment from the change in the parameters of the induction motor is ensured, a continuous range of speed regulation, including zero, and fast-acting regulation is ensured.

Keywords: asynchronous electric drive, rotor flux, changing the parameters of an induction motor

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Annual International Congress

Annual International Congress on Electrical Engineering

May 8-9, 2025
Oxford, United Kingdom

CONTRIBUTION OF MODELLING AN IP/MPLS NETWORK TRAVERSED BY MULTIMEDIA FLOWS (IPTV, VoD, Streaming DASH)

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Abstract

This study proposes an innovative modeling of IP/MPLS networks for multimedia flows, using queueing theory to analyze and predict their behavior. In a context of convergence of telecommunication technologies, the researchers developed a mathematical model based on an M/M/1 system, conducting tests on a real network and through simulation to evaluate the Quality of Service (QoS) at different bit rates. The results show remarkable latency stability up to 16 Mb/s, with a gradual increase in jitter and loss rate at higher bit rates, confirming the relevance of the approach. This research offers promising prospects for optimizing the management of multimedia flows in converged networks, addressing the growing challenges of performance and quality in modern digital services.

Keywords: TIC, VoIP, VoD, MPLS, IPTV, IP, DASH

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Annual International Congress

Annual International Congress on Electrical Engineering

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Modulators in the optical access network

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Abstract

The world is constantly changing, and Information and Communication Technologies (ICT) are playing a key role in this revolution.
Over the last ten years, customers' needs have evolved from a telephone-only offering, followed by the combination of Internet and television (xDSL) for medium bandwidth on the twisted copper pair, to offering high and very high bandwidth on fiber optics.
If this trend continues, it will be urgent to review the organization of the access network in order to increase throughput on this segment, with the introduction of modulators.
The modulators used in telecommunications networks are electro-absorbing and Mach Zehnder modulators. By simulating a network with FTTH/GPON architecture on Optisystem software using real data in an area of the city of Dakar, and gradually increasing the data rate, the performance of electro-absorbent and Mach Zehnder modulators will be measured and analyzed.

Keywords: External modulation; Modulators; Eye diagram; Bit Error Rate; Quality factor

Electrical Engineering
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Ferroresonance in three-phase electrical networks

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Abstract

Possible modes of ferroresonance in three-phase electrical networks and analysis of equivalent circuits where a ferroresonant increase in voltage is observed are considered. The most complete magnetization curve of the transformer core and an analysis of the generalized equivalent equivalent circuit are presented, as a result of which more accurate formulas are obtained for determining the values of the equivalent parameters of the electrical network and the voltage transformer in ferroresonance mode. A ferroresonant voltage increase coefficient has been introduced, which determines the relationship between the amplitude values of the phase voltage of the transformer and the network voltage. A method is given for determining the boundary conditions of a stable ferroresonant voltage increase using the example of calculating an energy-saving three-phase two-winding voltage transformer brand TMG12-250/15, as an important factor in the reliable operation of the electrical network. The results obtained can be used to analyze ferroresonance in power supply systems of both low and high voltage.

Keywords: Ferroresonance voltage boost; voltage transformer; core magnetization curve; generalized equivalent equivalent circuit; equivalent parameters; ferroresonance voltage boost coefficient; boundary conditions of stable ferroresonance

Electrical Engineering
Annual International Congress

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Artificial Intelligence and Machine Learning for Enhanced Security in Embedded Systems and IoT

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Abstract

This paper reviews the application of Artificial Intelligence (AI) and Machine Learning (ML) in addressing security challenges in embedded systems and IoT. Highlighting advancements and methodologies, it outlines key trends in AI/ML-driven solutions to detect and mitigate threats.

The proliferation of embedded systems and Internet of Things (IoT) devices has introduced unprecedented levels of connectivity and convenience. However, this rapid adoption has also brought significant security challenges. This paper reviews the application of AI and ML techniques in addressing security concerns in embedded systems and IoT. We explore recent advancements, key methodologies, and emerging trends, highlighting the potential of AI/ML to detect, prevent, and mitigate threats in these environments.

Keywords:Artificial Intelligence (AI); Machine Learning (ML); IoT Security; Embedded Systems; Security

Electrical Engineering
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Annual International Congress on Electrical Engineering

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Reducing Losses in Electricity Distribution Networks using Deep Neural Networks and the Three Lines of Defense (3LoD) Model: Case Study of Nigeria

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Abstract

Non-Technical Losses (NTL) affects financial and operational efficiency of electricity distribution networks globally, with developing economies such as Sub-Saharan Africa, bearing the most severe consequences of this challenge. Existing literature have primarily attributed NTL to theft by customers. However, there is increasing anecdotal and empirical evidence that utility staff activities significantly contribute to NTL, yet staff-related variables are still largely omitted in empirical research for NTL mitigation. This study presents a novel multi-disciplinary approach to reducing NTL, using Artificial Intelligence and Operational Risk Management to analyze a combined dataset of customer consumption and staff operations. A novel hybrid deep neural network was developed which combines the features extraction capabilities of convolutional neural network and classification capabilities of extreme gradient boosting with extensive hyperparameter optimization. Also, a SHAP-based novel features ranking algorithm was developed for model Explainability and the results of the experiment reveal that over 57% of top causes of NTL are staff-related. Consequently, NTL is framed within the context of operational risk by mapping the causes of NTL into operational risk cells(ORC) based on BASEL II and III risk definitions, and the Three Lines of Defense (3LoD) model is developed for NTL mitigation. By highlighting a significant omitted variable defect in existing literature, this work opens up a new conceptual and methodological perspective for understanding the broader drivers of NTL contrary to the earlier assumption that customers are the primary causes of NTL. The findings of this study are not limited to electricity distribution, but find relevance in other infrastructure-based sectors where customer/staff-centric approach are critical for efficiency optimization.

Keywords: Electricity Distribution; Non Technical Losses; Artificial Intelligence; Operational Risk;

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CONGESTION MANAGEMENT BY OPTIMAL PLACEMENT AND SIZING OF DG'S BY IEHO-TOPSIS APPROACH

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Abstract

With the global efforts to reduce greenhouse gases, along with renewable energy penetration, the use of Electric mobility is also increasing. The increasing presence of Electric Vehicles (EVs) requires a thorough understanding of their impact on distribution systems. A significant increase in charging load may create congestion in the existing distribution system. It affects the reliability of supply causing power quality issues. In this context, it is necessary to address the Active -time issue of Congestion Management (CM) at the distribution level by optimally siting and sizing the Distributed Generation (DG). Most of the research on distribution level congestion management provides the solution to this problem by locating the DG at the bus having the highest value of DLMP. However, for congestion management in the distribution system, along with objectives "congestion component of DLMP" is an important factor along with power loss minimization that needs to be considered. This paper proposes a strategy congestion management strategy using the "Multi-Criteria, Multi-Objective decision-Making Technique" based on the recently developed "IEHO-TOPSIS". In this strategy weights are given to multiple objective functions according to their priority for siting of DG and then optimal sizing of DG is carried out for CM. The objectives considered for the siting of DG are minimization of the 'congestion component of DLMP', Power loss minimization and voltage deviation minimization. The objectives considered for optimal sizing of DGs are Power loss minimization, voltage deviation minimization and voltage stability index maximization. This strategy is tested on a "modified IEEE 33 bus Radial Distribution system". The results show that the proposed strategy enhances the system's performance technically as well as economically. Congestion is mitigated significantly; power losses are minimized by almost 64% and the voltage profile is improved. This strategy is economically beneficial to the network/ microgrid operators as the objective function cost i.e. generation cost is also reduced by 63% to fulfil the increased load demand along with the existing demand. This method is generic as it can be implemented on any distribution network in static as well as dynamic conditions.

Keywords: Congestion Managemnet, Distributed Generatoe, Distribution locational marginal Price, optimization, Wind , Solar

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Contribution to the Optimisation of Grounding Resistances in Electrical Networks for Effective Lightning Protection

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Abstract

This research work deals with the optimisation of the resistances of grounding systems in electrical networks to protect them against lightning. In the face of increasing electrical disturbances, the study set out to assess the effectiveness of adjusting the distance between grounding electrodes in optimising the resistances of these systems. Simulations on the Djiri-Ngo line of the Congolese network show that, as well as increasing the number of electrodes, varying their distance also helps to reduce overall resistance. The results also show that each type of soil requires a specific configuration to achieve optimum resistance. This research highlights the importance of adapting earthing systems to local geological conditions in order to improve the safety of electrical infrastructures.

Keywords: Grounding electrode; Grounding resistance; Grounding system; Lightning protection; Optimisation