Proceedings of CONF-APMM 2025 Symposium: Controlling Robotic Manipulator Using PWM Signals with Microcontrollers
DOI: 10.54254/2753-8818/2025.AD28014

A Review of Applied Research on Artificial Intelligence Technology in Electrical Engineering Automation

Jiawei Wang

School of Electrical Engineering, Shanghai University of Electric Power, Shanghai, China
3627819931@ qq.com

Abstract. With the development of Industry 4.0, artificial intelligence (AI) technology is driving innovation in electrical engineering automation. This investigation rigorously examines the contemporary deployment of artificial intelligence within pivotal sectors, including intelligent grid enhancement, prognostic maintenance, and anomaly detection. The study emphasizes the efficacy of fundamental techniques such as model-based predictive regulation and multi-source sensor integration in augmenting performance. Results indicate that applying machine learning and deep learning algorithms increases system response speed by over 40% and reduces energy consumption by approximately 15%. Using a combined approach of literature review and case studies, this paper verifies the application value of AI technologies. It proposes optimization suggestions for key issues such as system compatibility and environmental adaptability, including innovative solutions like modular architecture and edge computing. The research outcomes offer pivotal insights for deploying intelligent control architectures within intricate industrial settings, bearing both theoretical import and practical relevance for catalyzing advancements in electrical automation.

Keywords: Artificial Intelligence, Intelligent Grid, Predictive Maintenance

1. Introduction

As Industry 4.0 progresses, artificial intelligence, a key driver of this technological revolution, is increasingly integrated into electrical engineering automation, propelling its evolution towards intelligent, efficient, and adaptive systems. Electrical systems are continuously expanding in scale and operating in increasingly complex environments. Traditional control methods gradually reveal limitations in dealing with high-dimensional nonlinear problems, multi-source heterogeneous data processing, and real-time dynamic response. In this context, AI technology,relying on its powerful data modeling, pattern recognition, and decision-making optimization capabilities, provides new technical pathways and research perspectives for electrical automation systems. In recent years, scholars domestically and internationally have conducted extensive theoretical and applied research focusing on smart grids, industrial robot control, and other directions, achieving numerous breakthroughs. However, existing research still has significant shortcomings in system compatibility, environmental adaptability, multi-modal information fusion, and the generalization ability of algorithms under complex working conditions, urgently requiring more systematic and in-depth exploration. Addressing the exigencies of electrical engineering automation, this paper elucidates the

© 2026 The Authors. This is an open access article distributed under the terms of the Creative Commons Attribution License 4.0 (https://creativecommons.org/licenses/by/4.0/).

DOI: 10.54254/2753-8818/2025.AD28014

application landscape of artificial intelligence in pivotal scenarios, scrutinizing the implementation modalities and outcomes of salient technologies, including machine learning, computer vision, and multi-sensor data fusion. Systematically reviewing the latest research results and typical engineering cases domestically and internationally, it aims to clarify the advantages and bottlenecks of current technological development, providing a clear problem orientation and methodological reference for subsequent related research and engineering practice.

2. Overview of key artificial intelligence technologies

2.1. Machine learning technology

As a core artificial intelligence technology, machine learning uses learning algorithms to automatically extract patterns and rules from historical data to build mathematical models with predictive and decision-making capabilities. Machine learning techniques are extensively employed in electrical engineering automation for tasks such as power load prediction, equipment fault categorization, electricity consumption pattern analysis, anomaly identification, equipment condition evaluation, and power system optimization and control.

2.2. Deep learning technology

Deep learning is an essential branch of machine learning. Its core involves building deep neural networks to automatically learn multi-level features and patterns from large amounts of data. Employing intricate architectures with numerous hidden layers, it performs hierarchical feature extraction and transformation, enabling high-fidelity recognition and prediction across modalities such as images, speech, and text, thus catalyzing advancements in artificial intelligence.

2.3. Computer vision technology

Based on the cross-integration of image preprocessing and image segmentation technologies, computer vision technology simulates the human visual system to achieve automatic understanding and analysis of image and video content. Electrical engineering automation is applied in intelligent inspection systems, visual monitoring of equipment status, and security monitoring systems.

3. Application of artificial intelligence in power systems

3.1. Smart grid optimization

Intelligent grid optimization is a primary direction for achieving efficient management of power systems, showing significant advantages in key links such as load forecasting, supply-demand balance, and fault handling. AI technology can perform deep mining of massive grid data, establish high-precision load forecasting models, predict changes in power demand trends in advance, and dynamically adjust power generation plans based on real-time feedback, significantly improving energy distribution efficiency. Deep learning algorithms exhibit robust feature extraction proficiencies when dissecting multi-dimensional parameters, such as historical electricity consumption data and meteorological metrics, precisely pinpointing electricity consumption patterns across diverse regions and temporal scales, thereby furnishing astute decision support for grid management [1]. Taking wind power generation as an example, through intelligent sensor networks and wind speed prediction algorithms, wind turbines can dynamically adjust the blade pitch angle

DOI: 10.54254/2753-8818/2025.AD28014

and rotation speed according to wind conditions to achieve maximum wind energy capture. At the wind farm cluster level, AI coordinates and controls each station's active and reactive power output, smoothing the total output curve and significantly reducing the impact of stochastic generation on the grid [2].

3.2. Power equipment fault diagnosis

The application of AI technology in power equipment fault diagnosis significantly improves power systems' operational efficiency and reliability. In the realm of high-voltage apparatus, machine learning paradigms, such as Support Vector Machines (SVM), demonstrate the capacity to precisely ascertain anomalous equipment conditions and forecast impending failures. This is achieved through real-time analysis of multidimensional parameters, including current, voltage, and temperature, thereby attaining a diagnostic precision exceeding 95% [1]. For common insulation faults, when the insulation resistance of a 10kV distribution line cable is detected to be below 0.5 MΩ, the system can provide early warning of phase-to-phase short circuit risk; for mechanical faults, vibration monitoring can timely detect generator rotor unbalance exceeding 0.15mm, avoiding bearing damage accidents [3]. Moreover, vigilant temperature surveillance is paramount, given that each incremental rise of 6°C in transformer winding temperature engenders a halving of insulation lifespan; erudite systems possess the capacity to modulate loads dynamically, thereby protracting the operational longevity of equipment [4]. In low-voltage electrical systems, intelligent monitoring of contactors has made significant breakthroughs. By collecting signals such as core vibration and coil current, the system can accurately identify typical faults such as mechanical blockage and insufficient voltage. Compared with traditional offline detection, this AI-based online monitoring method improves detection efficiency by over 40% while reducing maintenance costs by 30%. Harmonic interference monitoring is also essential; when the total harmonic distortion rate of the system exceeds 5%, it can promptly warn of risks such as transformer overheating and capacitor overcurrent. The comprehensive application of these intelligent diagnostic technologies has reduced the average repair time (MTTR) for power equipment faults by 60%, providing a strong guarantee for the safe and stable operation of the power grid [5].

4. Application and improvement of artificial intelligence in industrial automation

4.1. Robotics technology and automated handling

In industrial automation, the control system design of intelligent handling robots is key to achieving efficient and precise operations. Adopting Model Predictive Control (MPC) and state estimation algorithms allows the system to optimize the robot's motion trajectory and adjust control strategies in real-time, significantly enhancing its adaptability and stability in complex environments. Multi-sensor fusion technology integrates devices such as LiDAR, vision, and inertial measurement units (IMU), combined with advanced filtering algorithms, achieving high-precision environmental perception and positioning. Experimental verification shows this control system performs excellently in response speed, positioning accuracy, and path planning efficiency, especially demonstrating outstanding obstacle avoidance capability and adaptability in dynamic environments [6]. Adopting a modular architecture and unified data interface standards (such as OPC UA) and developing adaptive data fusion algorithms to solve multi-source sensor compatibility issues is recommended to enhance the system compatibility of intelligent handling robots. For environmental adaptability, it is recommended to combine reinforcement learning to adjust control parameters

DOI: 10.54254/2753-8818/2025.AD28014

dynamically, adopt multi-modal perception fusion to enhance positioning reliability, and establish an environmental feature database for rapid working condition recognition.

4.2. Predictive maintenance

In the field of predictive maintenance, AI-based predictive maintenance systems collect equipment operational data in real-time by deploying multiple types of sensors, perform efficient cleaning and feature extraction combined with a big data platform, and utilize deep learning models (such as Convolutional Neural Networks - CNN and Long Short-Term Memory networks - LSTM) to analyze multi-source heterogeneous data, achieving early fault prediction and health status assessment. Empirical validation demonstrates that the system achieves a prediction accuracy exceeding 95% for insulation, thermal, and mechanical faults, while maintaining health status assessment error within a controlled margin of 6%. These results represent a significant improvement over conventional manual inspection methodologies [3]. Its layered architecture covers data acquisition, processing, intelligent analysis, and decision application, supporting closed-loop management from real-time monitoring to maintenance strategy generation. Through an adaptive learning mechanism, the system can dynamically optimize models to adapt to changes in equipment status, while an expert rule library can automatically generate targeted maintenance plans. To bolster the system's robustness and generalization capabilities within intricate industrial settings, I propose integrating an edge computing paradigm for on-site data processing, thereby mitigating transmission delays. Simultaneously, develop lightweight deep learning models to adapt to the computing power of different devices and establish a standardized fault feature library to improve cross-device diagnostic capability.

5. Application of artificial intelligence in special scenarios

5.1. Agricultural machinery electrical monitoring

The AI-driven automated electrical monitoring system for agricultural machinery employs a multi-sensor fusion approach—integrating vibration, temperature, and current data—with an edge-cloud computing framework. This synergy enables holistic sensing and intelligent analytics of the electrical system's operational status in agricultural machinery. The system uses Deep Convolutional Networks (DCNN) for fault diagnosis and Long Short-Term Memory networks (LSTM) for predicting component remaining useful life (RUL). Empirical evidence indicates that the diagnostic precision of this method for prevalent anomalies, including insulation degradation and contact deficiencies, attains an average of 95.2%. Furthermore, the system exhibits a rapid alert latency of merely 2.5 minutes. This represents a marked improvement over conventional threshold-based methodologies, which demonstrate an accuracy of 82.5% and a response interval of 30 minutes [7]. For optimization, it is recommended to select MEMS sensors with IP67 protection rating to improve anti-interference capability, optimize the edge-cloud collaboration mechanism, deploy lightweight models at the edge layer for real-time preprocessing; adopt standardized communication protocols (CAN bus, Industrial Ethernet) to enhance device compatibility, and introduce transfer learning and attention mechanisms to improve the model's generalization ability across different agricultural machinery models and working conditions. These refined optimizations will bolster the system's robustness, interoperability, and adaptability within intricate agricultural settings, thereby furnishing dependable technical resources for intelligent farm machinery surveillance.

DOI: 10.54254/2753-8818/2025.AD28014

5.2. Automated control in new energy development

In the process of new energy development, electrical engineering automation control systems effectively address the intermittency and volatility challenges of renewable energy sources like wind and solar power through AI technology, significantly improving power generation efficiency and grid stability. Employing big data analytics in conjunction with machine learning and deep learning algorithms, the system facilitates new energy output forecasting, equipment condition surveillance, and intelligent resource allocation. For example, it optimizes the operating status of wind turbines and photovoltaic arrays through wind speed and light intensity prediction, uses Maximum Power Point Tracking (MPPT) control to improve photoelectric conversion efficiency, and employs intelligent charging/discharging strategies for energy storage systems to smooth power fluctuations [2]. To bolster system resilience and interoperability, it suggest establishing a cohesive communication framework within renewable energy electrical automation systems, leveraging standardized interfaces and protocols to optimize multi-device collaborative performance. Furthermore, it propose facilitating the integration of streamlined AI models at the network edge to curtail response delays and reliance on network infrastructure. Finally, it recommend incorporating safety redundancy protocols and adaptive fault-tolerant methodologies to augment system robustness amidst variable operational scenarios. Simultaneously, cross-platform data standards should be established to strengthen multi-source data fusion and interoperability capabilities, supporting stable operation and efficient integration in complex environments.

5.3. Automatic control of ship electrical equipment

Aiming at the' complex and variable working environment of ships, the ship electrical equipment control system collects equipment operational data in real-time through various types of sensors. It uses machine learning algorithms to analyze historical data, optimizing operating parameters of key equipment such as generators. After intelligent upgrades using AI technology, the system can utilize deep learning models for fault prediction and diagnosis, accurately identifying abnormal patterns and providing early warnings. The architecture employs a modular approach, comprising discrete modules for data acquisition, processing, intelligent analytics, and control output. This design ensures operational resilience, maintaining system stability even in the event of individual node failures. Empirical results demonstrate the system's adaptability to diverse operational environments, exhibiting a response time improvement exceeding 40% relative to conventional techniques. In comparison, intelligent adjustment can reduce energy consumption by about 15%. This intelligent control system significantly enhances the safety and reliability of the ship's power system, providing an effective solution for applications in harsh environments [8]. Intelligence and unmanned operation have become important directions in ship technology development. In order to meet the ship's horizontal communication (machine-to-machine) and vertical communication (interconnection between control network and management network) needs, standardised communication protocols and ship intelligent decision-making technology can be used to further improve system compatibility and stability. This will increase the ship system's stability under a variety of working conditions [9].

6. Conclusion

This study systematically analyzed the application status of artificial intelligence in electrical engineering automation, focusing on its technical advantages in areas such as intelligent grid

DOI: 10.54254/2753-8818/2025.AD28014

optimization, predictive maintenance, and ship electrical control. The study demonstrates how multi-sensor fusion and adaptive optimisation methods greatly enhance system performance metrics in intelligent control systems based on machine learning and deep learning. In response to existing technical challenges, the optimization solutions proposed in this paper, such as modular architecture, edge computing, and lightweight models, hold significant reference value. Future research should focus on developing standardised protocols and enhancing algorithm generalization capabilities to promote the deeper application of AI technology in industrial automation.

References

[1] Shen, Y. Y. (2025). Application of Artificial Intelligence Technology in Electrical Engineering Automation. Information Recording Materials, 26(2), 138-140. doi: 10.16009/j.cnki.cn13-1295/tq.2025.02.076.
[2] Xu, Y. (2025). Analysis of Electrical Engineering Automation Control Strategies in the Process of New Energy Development. Science and Technology & Innovation, (9), 219-221+225. doi: 10.15913/j.cnki.kjycx.2025.09.057.
[3] Zhang, J. (2025). Research on the Design of an Intelligent Maintenance System for Electrical Equipment Based on Artificial Intelligence. Electrical Engineering and Economics, (5), 125-127+130.
[4] Zhong, Y. L., & Luo, X. (2024). Analysis and Treatment Measures of a Valve Cooling Spray Water Fault in a Converter Station. Heilongjiang Electric Power, 46(4), 347-350+359. doi: 10.13625/j.cnki.hljep.2024.04.013.
[5] Sun, J. (2025). Design and Application of an Automated Fault Detection System for Intelligent Electrical Contactors Based on Artificial Intelligence. Information Recording Materials, 26(4), 72-74. doi: 10.16009/j.cnki.cn13-1295/tq.2025.04.072.
[6] Xu, D. F. (2024). Discussion on the Application of Artificial Intelligence in Electrical Engineering Automation. China Equipment Engineering, (6), 28-30.
[7] Si, R. L. (2025). Research on Automatic Electrical Monitoring Technology for Agricultural Machinery Based on Artificial Intelligence. Southern Agricultural Machinery, 56(3), 70-72.
[8] Zhou, J. L. (2025). Application of Artificial Intelligence in Automatic Control of Ship Electrical Equipment.Ship& BoatMaterialsandMarket, 33(3), 115-117.doi: 10.19727/j.cnki.cbwzysc.2025.03.036.
[9] Zhao, X. Y., Zhao, Y., & Jiang, K. Y. (2024). Research and Prospect of Intelligent Standard Communication Protocol for Ships Based on OPC-UA. Marine Electric & Electronic Technology, 44(6), 31-35. https: //doi.org/10.13632/j.meee.2024.06.009.