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Integrated Innovative Applications of Artificial Intelligence and Electrical Automation Technology

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Abstract: The integrated innovation of artificial intelligence and electrical automation technology not only represents a further innovation of traditional models but also promotes the innovative development of both artificial intelligence and electrical automation technology. This paper delves into the significance of the integrated innovative applications of artificial intelligence and electrical automation technology, as well as the strategies for such applications, aiming to better achieve the intelligent development of electrical automation technology.

Keywords: Artificial intelligence; Electrical automation technology; Integrated innovation

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1. Introduction

According to "Guidelines on Accelerating the Cultivation and Development of High-Quality Manufacturing Enterprises," high-quality manufacturing enterprises focus on the real economy, excel in their main businesses, possess strong innovation capabilities, high quality-efficiency ratios, and significant industrial driving effects, playing the leading and vanguard roles in the construction of a manufacturing-power country. Accelerating the cultivation and development of high-quality manufacturing enterprises is an inevitable requirement for stimulating the vitality of market entities and promoting the high-quality development of the manufacturing industry. It is also an urgent need to prevent and defuse risks and enhance the independent and controllable capabilities of the industrial chain and supply chain. To implement the decision-making and deployment of the Central Committee of the Communist Party of China and the State Council and accelerate the cultivation and development of high-quality enterprises represented by "little giant" enterprises specializing in and excelling in specific niches, manufacturing single-champion enterprises, and industrial chain-leading enterprises (hereinafter referred to as "little giant" enterprises, single-champion enterprises, and leading enterprises), it is necessary to formulate and improve selection criteria for different categories, select and establish benchmarks for "little giant" enterprises, single-champion enterprises, and leading enterprises. It is also essential to improve the gradient cultivation mechanism, guide

"specialized, refined, characteristic, and innovative" small and medium-sized enterprises to grow into domestic market-leading "little giant" enterprises, guide various enterprises such as "little giant" enterprises in key industries and fields to grow into international market-leading single-champion enterprises, and guide large enterprise groups to develop into leading enterprises with ecological dominance and international competitiveness [1]. The state attaches great importance to manufacturing enterprises. Universities should cultivate talents through national policy documents to better promote the comprehensive development of students.

2. Significance of the integrated innovative applications of artificial intelligence and electrical automation technology

2.1. Contributing to the stable operation of the system

Operators can utilize the real-time monitoring function of artificial intelligence technology to detect potential problems in advance, enabling better prevention. The system can identify abnormal situations in equipment through artificial intelligence algorithms and take pre-established measures to prevent the impact of failures, ensuring the normal operation of the equipment. In the past, control methods were often based on fixed rules, and operators would be at a loss when facing complex problems [2]. With the development of artificial intelligence, operators can make dynamic adjustments through data-driven methods, better cope with uncertain problems and factors, and ensure the stable operation of the system. Artificial intelligence technology also supports intelligent optimization and decision-making. The system can learn the optimal operation mode and parameter settings by analyzing historical data, thus operating more effectively.

2.2. Reducing the costs of electrical automation control

Traditional electrical automation control usually requires a large amount of human participation and operation. The introduction of artificial intelligence technology enables unmanned operation, transforming manual labor into the autonomous operation of mechanical equipment. This not only improves work efficiency but also reduces labor and maintenance costs. Firstly, artificial intelligence technology can achieve intelligent optimization and energy-saving management of equipment through data analysis and prediction. By collecting and analyzing a large amount of real-time data, the system can conduct precise control and adjustment according to actual situations, achieving the optimal utilization of energy and reducing energy consumption and operating costs [3]. Secondly, artificial intelligence technology can enhance the reliability and stability of electrical equipment, thereby reducing production losses caused by failures and downtime. Through real-time monitoring and fault prediction, the system can issue alarms promptly and take corresponding measures to prevent the further expansion of failures. Finally, artificial intelligence technology can optimize supply chain management, realizing the effective scheduling and utilization of materials and resources. By analyzing market demands, predicting sales trends, and optimizing production plans, the system can achieve precise inventory management and material procurement, thus reducing inventory and transportation costs [4].

2.3. Enhancing the operability of electrical automation control

With the development of the times, artificial intelligence technology based on the intelligent concept has been widely applied in various industries, changing the traditional work model. In the aspect of electrical control equipment, the application of intelligent technology simplifies operation. Only by mastering relevant technologies proficiently can operators effectively prevent equipment failures and ensure the reliable operation of the electrical

control system. Artificial intelligence technology can not only effectively reduce the probability of human errors but also relieve workers' work pressure, greatly improving production efficiency and quality [5]. In recent years, with the continuous development of artificial intelligence technology, the operability of electrical equipment has been significantly improved. It can meet the needs of various industries, support personalized function design, provide great convenience for various industries and enterprises, and greatly enhance the level of electrical automation control [6].

3. Strategies for the integrated innovative applications of artificial intelligence and electrical automation technology

3.1. Application of artificial intelligence technology in electrical equipment design

In traditional electrical equipment design, it often relies on designers' experience or repeated experimental adjustments. Nowadays, designers can provide more intelligent and efficient reform solutions for users by deeply mining and analyzing a large amount of historical design data and model cases in artificial intelligence, thereby improving the performance and operation of electrical equipment [7]. Students learning the design results driven by artificial intelligence can systematically optimize the product development process, saving a certain amount of human, material, and financial resources for enterprises. At the same time, it shortens the cycle from product concept to market and improves the quality standard of design results. Teachers explain that in this process, the genetic algorithm is mainly used to encode the decision-making variables, constructing a search mechanism guided by fitness, and finally outputting the optimal or sub-optimal design plan. This process effectively improves the scientificity and rationality of electrical system design, providing a solid technical support for the continuous evolution of electrical automation technology. Through the above-mentioned learning, students can continuously master the application of artificial intelligence technology in electrical equipment design and better apply it to enterprise practices during employment. Based on this, they can also propose some new development directions [8].

3.2. Application of artificial intelligence technology in electrical equipment fault diagnosis

The application of artificial intelligence technology in electrical equipment fault diagnosis is gradually realizing an intelligent transformation from passive response to active prediction. For example, the Double-RNN model developed by Li *et al*. constructed an automated processing chain for data features extraction and fault classification through a double-layer recurrent neural network architecture [9]. This model can analyze device operation parameters such as temperature and current in real-time. When abnormal fluctuations are detected, it can automatically trigger the feature extraction layer for multi-dimensional data analysis and quickly locate the fault location through the classification prediction layer. Experiments show that its average accuracy reaches 90.06%, an increase of 5-8 percentage points compared with traditional algorithms. Song and Tian proposed a graph attention neural network that further strengthens the fault correlation analysis ability. By constructing a node vector model of the device topology graph, it can accurately capture the abnormal feature correlations of key components such as circuit breakers and disconnectors, achieving a 98.3% fault recognition accuracy rate in a 20-meter distance positioning detection [10]. In terms of complex-scene adaptability, Tao and Yin designed a convolutional neural network that, combined with the transfer learning mechanism, transfers the pre-trained model parameters to the diagnosis scenarios of new devices. It can restore 95.6% of the diagnostic accuracy in only 20 training cycles, significantly shortening the deployment cycle of new device models [11]. Yang's team-developed wavelet neural network diagnosis system uses multi-scale time-frequency analysis technology to decouple the phase information

of secondary equipment, reducing the fault detection response time of relay protection devices to 0.87 seconds and controlling the false alarm rate below 1.9% [12]. These technological breakthroughs are promoting the transformation of electrical equipment operation and maintenance from traditional manual inspection to digital transformation featuring intelligent perception and autonomous decision-making.

3.3. Application of artificial intelligence technology in the steel industry

In the wave of intelligent transformation in the steel industry, artificial intelligence technology is deeply integrated into the entire chain of production management and operation decision-making. Take Nanjing Iron and Steel as an example. It's a constructed intelligent energy central control center that uses multi-variable intelligent optimization technology to achieve horizontal integration of the energy system and vertical tracking of carbon emissions. This reduces the process energy consumption by 3% and increases the self-generated electricity ratio by 5%, creating an annualized benefit of nearly 200 million yuan [13]. Baosteel Zhanjiang Base has innovatively developed a scrap steel production-cost model. By using machine-learning algorithms to analyze the correlation between the cost-performance of scrap steel and smelting parameters, it has established a dynamic economic evaluation system has been successfully established, successfully increasing the scrap steel ratio to 15% and optimizing the cost per ton of steel [14]. In the field of quality traceability, Ansteel has developed a scrap steel intelligent management system that integrates instance segmentation algorithms and 3D vision technology, constructing a "steel face" feature database to achieve full-life-cycle traceability of lump-type scrap steel, with a hazardous substance recognition accuracy rate of 99% [15]. In terms of market analysis, the time-series prediction model jointly developed by China Steel Net and Tencent, based on the EEMD-Transformer-ARIMA combined algorithm, can dynamically deduce the price fluctuations of six categories of products such as hot-rolled coils and rebar, with a prediction accuracy 12.6% higher than that of traditional models [16]. It is worth noting that Bayi Steel has innovatively integrated knowledge graphs and large-language models to construct an index inference engine covering production, equipment, and energy consumption. This enables non-technical personnel to obtain real-time decision-making suggestions through natural language interaction, increasing the response efficiency to abnormal working conditions by 40% [17]. These practices show that artificial intelligence technology is evolving from single-point breakthroughs to system integration, promoting the steel industry to form a new production paradigm of "data-driven decision-making, algorithm-optimized processes, and intelligent reconstruction of the ecosystem."

3.4. Application of artificial intelligence technology in condition monitoring

In the earliest stage of the development of the electrical engineering discipline, due to the constraints of hardware computing power and algorithm complexity, it was difficult to process faults and problems quickly and efficiently. In traditional automatic control systems, when a fault occurred, an alarm would sound to draw the attention of relevant technicians to the potential problem, who would then handle it. After hearing the alarm, technicians in traditional inspections often had to find the problem through inspections and investigations, and then make adjustments. These methods might overlook some areas or result in incomplete data collection. The emergence of artificial intelligence enables intelligent detection of electrical systems, reducing the need for excessive human input and providing accurate data. By continuously comparing real-time data streams with prediction models, artificial intelligence technology can detect problems more quickly, issue reminders, and promptly adopt corresponding strategies to avoid production interruptions [18].

3.5. Application of artificial intelligence technology in remote control

The traditional manual operation mode has significant problems when dealing with large-scale and complex electrical systems: First, it is difficult for manual monitoring to comprehensively observe the operation of equipment; second, the safety of operators in high-risk environments is at risk, and it is difficult to accurately identify problem areas; third, the density and status of electrical equipment in space-time distribution are constantly changing, so relying solely on operators for fault diagnosis and control decision-making can no longer meet the system requirements. Therefore, operators can use artificial intelligence technology to address these issues. For example, the system can continuously monitor electrical equipment better through artificial intelligence learning. Through feature extraction and pattern recognition technology, the system can convert key information such as abnormal equipment appearance and operation status into structured data, facilitating operator operation. This allows operators to control the equipment remotely without having to constantly monitor the changing situation, improving operator safety and operation accuracy [19].

3.6. Application of artificial intelligence technology in data collection and processing

Traditional data collection is carried out manually through fixed sensor networks, resulting in certain blind spots and response lags. However, the system can scan the surface of equipment better through computer vision technology, enabling the detection of fine cracks. The system can also identify abnormal situations during equipment operation by using sound-processing technology and monitor temperature changes through thermal imaging technology. Artificial intelligence can provide intelligent solutions for operators through data cleaning. For example, in traditional data annotation, it was all done manually. With the advent of artificial intelligence, a large amount of manpower can be saved while ensuring more accurate data processing. Decision-making optimization can better transform the value of data. The system can clean historical data, update the probability of faults in real-time, and make better predictions.

4. Conclusion

The deep integration of artificial intelligence and electrical automation technology marks an important leap from traditional industrial control to intelligent and digital transformation. This paper analyzes the innovative application scenarios and values of artificial intelligence technology from key aspects such as equipment design, fault diagnosis, industrial applications, condition monitoring, remote control, and data collection. For example, Nanjing Iron and Steel has achieved energy-saving and efficiency-improvement in the energy system through multi-variable intelligent optimization technology, Baosteel Zhanjiang Base has optimized the scrap steel ratio based on machine learning to reduce the cost per ton of steel, and Ansteel has constructed a full-life-cycle traceability system for scrap steel with the help of 3D vision and instance segmentation algorithms. These practical cases verify the feasibility of technology implementation and highlight its significant advantages in improving production efficiency, ensuring system stability, and reducing operating costs. It can be foreseen that with technological iteration and ecological improvement, the integrated innovation of artificial intelligence and electrical automation will not only reshape the production paradigm of the manufacturing industry, but also inject sustainable momentum into the global industrial intelligent upgrade.

Disclosure statement

The authors declare no conflict of interest.

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