Analysis of the Intelligent Integration Application and Development Trend of Electric Systems

Wei Wei[1]
[1]College of Mechanical and Electrical Engineering, Wuhan City Polytechnic, Wuhan, Hubei, China
Corresponding author: Wei Wei (e-mail: Wei306527000@163.com).

ABSTRACT With the deep integration of information technology and electrical engineering, intelligent integration of electrical systems has become an important force in promoting energy structure improvement and industrial transformation and upgrading, playing a key supporting role in the intelligent upgrading of traditional manufacturing sectors such as textiles and leather. This paper systematically analyzes the technological foundation, application scenarios, and development trends of intelligent integration of electrical systems. It outlines the technological framework consisting of intelligent sensing, IoT architecture, and artificial intelligence algorithms, analyzes the application paths of typical scenarios such as smart grids, energy management, and new energy dispatching, and reflects on cutting-edge issues such as digital twins, cybersecurity, and standards and talent. It aims to provide some reference for the intelligent upgrading of electrical systems and high-quality energy development in the textile industry..

INDEX TERMS Electrical Systems, Intelligent Integration, Textile Industry, Internet of Things, Development Trends.

I. INTRODUCTION

Electricity is a vital energy source for modern society, and the safety, efficiency, and green operation of its systems directly impact the overall economic and social development. In recent years, with the rapid development of next-generation information technologies such as artificial intelligence, the Internet of Things, big data, and cloud computing, power systems have gradually shifted from single-control methods to multi-dimensional intelligent integration. Intelligent integration can improve the efficiency and reliability of power system operation, providing strong support for energy structure adjustment and green development. Against this backdrop, in-depth research on the technological paths, current applications, and development trends of intelligent integration in power systems is of significant theoretical and practical importance for promoting the transformation and upgrading of the power industry and contributing to the realization of the national "dual-carbon" strategy.

II. TECHNICAL FOUNDATION AND CORE ARCHITECTURE OF INTELLIGENT INTEGRATION OF POWER SYSTEMS

1) WIDESPREAD DEPLOYMENT OF INTELLIGENT SENSING AND DATA ACQUISITION TECHNOLOGY IN ELECTRICAL SYSTEMS

Intelligent sensing and data acquisition technology is a fundamental part and an important support for the intelligent integration of power systems. High-precision voltage, current, temperature, vibration and environmental parameter sensors are deployed in various links of power generation, transmission, distribution and consumption to realize the dynamic perception of the operating status in all aspects, all weather and all elements [1]. New intelligent sensing devices based on microelectromechanical systems and wireless communication technology are small in size, low in power consumption, high in precision and strong in self-organizing network capability, and can collect a large amount of multi-source heterogeneous data in real time [2].

2) SYSTEM INTEGRATION ARCHITECTURE BASED ON IOT AND CLOUD-EDGE COLLABORATION

The Internet of Things and cloud-edge collaborative architecture provide a stable and scalable architecture and operating platform for the intelligent integration of power systems. Relying on the organic integration of the four layers of perception layer, network layer, platform layer and application layer, devices can be interconnected, data can be shared and services can cooperate with each other [3].

Edge computing nodes complete real-time data processing, local analysis and rapid response, thereby reducing the pressure on network bandwidth and end-to-end latency, while cloud computing platforms store a large amount of data, model global optimization models and schedule cross-regional resources [4].

3) ARTIFICIAL INTELLIGENCE ALGORITHMS AND BIG DATA ANALYSIS PROVIDE SUPPORT FOR INTELLIGENT DECISION-MAKING

Artificial intelligence algorithms and big data analysis technology are the main driving force and intelligent brain for the realization of intelligent decision-making in power systems. By adopting advanced methods such as deep learning, reinforcement learning, knowledge graphs, and data mining, we can obtain in-depth modeling, feature extraction, and correlation analysis from a large amount of historical operation data and real-time collected data, and then accurately find the hidden operation rules, abnormal features, and evolution trends [5]. Artificial intelligence technology has obvious advantages over traditional methods in important business scenarios such as load forecasting, fault identification, optimized scheduling, and risk assessment.

III. TYPICAL APPLICATION SCENARIOS OF INTELLIGENT INTEGRATION OF ELECTRICAL SYSTEMS

1) LOAD FORECASTING, FAULT DIAGNOSIS AND SELF-HEALING CONTROL IN SMART GRIDS

The smart grid is the most typical scenario of intelligent integration of power systems and the result of deep integration of modern power technology and information technology. By using multi-source data acquisition, artificial intelligence analysis and other technical means, the smart grid can accurately predict short-term, medium-term and long-term loads, and provide scientific and reasonable basis for power generation planning, unit combination optimization and economic dispatch decision-making, thereby improving the power supply and demand balance level and resource allocation efficiency. The intelligent algorithm relies on multiple information such as synchronous phasor measurement, traveling wave ranging and fault recording to quickly and accurately find the fault point and determine the fault type and nature, thereby greatly reducing the time for finding outages [7]. The self-healing control system relies on the cooperation between intelligent switches, flexible interconnection devices and distributed control strategies to automatically isolate the fault area when a fault occurs, thereby ensuring the power supply of non-fault areas and truly realizing the continuity and security of power supply [8]. It can also adapt well to various different situations [6]. The technical indicators of the core functions of the smart grid are compared in Table 1.

TABLE 1. Comparison of Core Functional Technical Indicators of Smart Grid

Functional Modules	Response Time	Accuracy	Main Technical Means
Load forecasting	Minutes	More than 95%	Deep learning, multi-source data fusion
Fault Diagnosis	millisecond level	More than 98%	Synchronous phasor, traveling wave ranging
Load forecasting	Minutes	More than 95%	Deep learning, multi-source data fusion
Self-healing control	Seconds	More than 99%	Smart switches, distributed control

2) ENERGY CONSUMPTION MONITORING AND SMART ELECTRICITY MANAGEMENT IN THE INDUSTRIAL AND BUILDING SECTORS

The industrial and building sectors are the main terminal links of electricity consumption and also the scenarios where intelligent integration of power systems plays an important role. Advanced sensing devices such as smart meters, energy consumption monitoring terminals, and data acquisition gateways are used to monitor, measure, and analyze the electricity consumption of production workshops, office buildings, and public buildings in real time. In high-energy-consuming industries such as textiles, leather, chemicals, and metallurgy, intelligent power management systems can find weak links and waste points in the production process, and achieve the goal of energy saving, consumption reduction, and green production by optimizing equipment start-up and shutdown strategies, rationally allocating loads, and improving operating parameters [9]. In commercial and public buildings, relying on environmental parameters, personnel activities, indoor comfort, and other information, intelligent systems can dynamically and accurately adjust electrical equipment such as lighting, air conditioning, ventilation, and elevators, and achieve a dual consideration of energy comfort and economy [10]. The energy-saving effects of intelligent power management in different application scenarios are shown in Table 2.

TABLE 2. Energy-Saving Effects of Smart Electricity Management in Typical Scenarios

Application scenarios	Monitoring objects	Energy efficiency	Investment recovery period
Textile and leather workshop	Production equipment, air compressor system	15%–20%	2–3 years
Commercial office buildings	Lighting and air conditioning systems	20%–25%	3–4 years
Public buildings	Ventilation and elevator equipment	10%–15%	3–5 years

3) INTELLIGENT SCHEDULING AND OPTIMIZED OPERATION OF NEW ENERGY GRID CONNECTION AND ENERGY STORAGE SYSTEMS

With the large-scale development of renewable energy such as wind power and photovoltaics and the rapid growth of installed capacity, the intelligent scheduling and operation of new energy grid connection and energy storage system has become an important application area and research hotspot of intelligent integration of power system. Due to the obvious intermittent, fluctuating and uncertain characteristics of new energy power generation, traditional scheduling methods are difficult to deal well with the grid impact and balance problems caused by it [11]. The intelligent scheduling system relies on a lot of data resources such as meteorological forecast, power forecast and real-time monitoring, and integrates machine learning and optimization algorithms to achieve accurate prediction of new energy output and reasonable acceptance. The energy storage system uses advanced battery management, bidirectional converter control and energy management technology to charge and store during the load trough and discharge during the load peak, thereby smoothing the fluctuation of new energy output and adjusting the supply and demand balance of the system [12]. The key operating parameters of new energy grid connection and energy storage system are detailed in Table 3.

TABLE 3. Key Operating Parameters of New Energy Grid Connection and Energy Storage Systems

System type	Power prediction accuracy	Response speed	Adjustment ability
Wind power forecasting system	85%–90%	15-minute level	Intraday scheduling
Photovoltaic forecasting system	88%–92%	15-minute level	Intraday scheduling
Energy storage regulation system	—	millisecond level	Peak shaving and valley filling

IV. DEVELOPMENT TRENDS AND CHALLENGES OF INTELLIGENT INTEGRATION OF ELECTRICAL SYSTEMS

The future development of intelligent integration of power systems presents an evolutionary pattern of three-in-one integration of technology upgrading, security assurance and system support, and its internal logical relationship is shown in Figure 1.

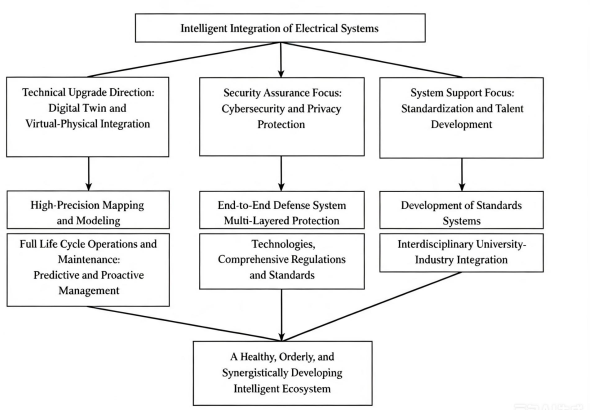

Fig. 1. Logical Relationship between the Development Trends and Challenges of Intelligent Integration in Electrical Systems.

1) DIGITAL TWINS AND VIRTUAL-PHYSICAL INTEGRATION DRIVE THE UPGRADE OF SYSTEM OPERATION AND MAINTENANCE MODELS

Digital twin technology is an achievement of the deep integration of new-generation information technology with electrical systems, and it is bringing profound changes and comprehensive upgrades to the operation and maintenance of the system. Creating a high-precision, full-element, multi-dimensional mapping model of the physical electrical system in the virtual digital space can achieve the purpose of real-time synchronization, accurate backtracking and dynamic development of the real equipment and the entire system operation status. The digital twin integrates multi-source heterogeneous data, mechanism models and artificial intelligence algorithms, and can dynamically display the operating parameters, health status, asset performance and development trend of the electrical system, and provide operation and maintenance personnel with an intuitive, comprehensive and three-dimensional decision support platform. Digital twin technology can predict equipment failure and health status in advance, and can improve the service life of equipment and reduce the probability of unplanned downtime and the increase in operation and maintenance costs caused by equipment downtime [13]. Digital twin gives new means to system planning, design and optimization. It allows people to carry out various scheme experiments, comparisons and improvements in the digital space, thereby avoiding the risks and costs caused by actual transformation. The virtual-real integration operation and maintenance model breaks through the constraints of traditional "post-event maintenance" and "periodic inspection", prompting the power system to develop in a predictive, proactive and lean direction of operation and maintenance, integrating the data-driven smart operation and maintenance concept into the management of the entire life cycle, thereby significantly improving the efficiency of power equipment asset management, operation economy and the overall safety level of the system [14].

2) NETWORK SECURITY PROTECTION AND DATA PRIVACY PROTECTION FACE NEW CHALLENGES

The intelligent integration of power systems has brought numerous benefits to improved operational efficiency, service levels, and business models. However, it has also made network security and data privacy protection increasingly prominent, becoming a significant factor affecting industry development. With the rapid expansion of networked equipment, the dramatic increase in data interaction frequency, and the continuous expansion of application scenarios, the network attack surface faced by power systems is constantly expanding, and security threats are becoming increasingly diverse, complex, and covert. Security incidents such as malicious code implantation, denial-of-service attacks, data tampering and theft, and control command hijacking occur frequently, posing serious threats and destructive impacts on power supply continuity, production safety and stability, and social order. Simultaneously, the large amounts of data collected, processed, and stored by power systems during operation contain sensitive information such as user electricity consumption behavior, production process parameters, enterprise operating information, and critical infrastructure layout. Leakage, misuse, or illegal transactions could cause incalculable serious consequences and chain reactions. Establishing a comprehensive security defense system covering perception, transmission, storage, processing, and application, and comprehensively utilizing multiple layers of security protection technologies such as identity authentication, access control, data encryption, intrusion detection, situational awareness, and security auditing, has become an urgent need and a major challenge for ensuring the safe and stable operation of power systems. In addition, new technologies such as privacy computing, federated learning, and blockchain have been applied to data protection and data value mining, data sharing and circulation, and data collaborative analysis, providing people with a new way to carry out data value mining, sharing and circulation and collaborative analysis while ensuring data privacy [15].

3) THE IMPROVEMENT OF THE STANDARDS SYSTEM AND THE CULTIVATION OF INTERDISCIPLINARY TALENTS NEED TO BE PROMOTED IN A COORDINATED MANNER.

Intelligent integration of electrical systems involves a deep cross-disciplinary integration of numerous disciplines, including electrical engineering, information technology, automatic control, artificial intelligence, and materials science. Therefore, the establishment of a sound standard system and the cultivation of interdisciplinary talents are crucial and urgent. Currently, the relevant technical standards for intelligent electrical systems are incomplete. Different manufacturers use different equipment interfaces, have incompatible protocols, different data formats, and significantly different functional descriptions, resulting in difficulties in system integration, low interoperability rates, and slow large-scale application. There is an urgent need for coordinated national and industry-level efforts to promote standardization at the top-level design and system construction levels. This includes developing fundamental and universal technical standards and specifications covering key aspects such as equipment access, data exchange, security protection, testing and evaluation, and operation and maintenance management. This will build a complete standard system framework covering the entire industry chain and the entire life cycle, providing a solid standard foundation and technological guidance for intelligent integration of electrical systems. In terms of talent cultivation, the traditional electrical engineering education model can no longer meet the diverse and high-level demands of intelligent integration for talents in terms of knowledge structure, abilities, and innovative thinking. Higher education institutions must continuously promote interdisciplinary integration, optimize and adjust curriculum systems and teaching content, and organically and deeply integrate cutting-edge disciplines such as artificial intelligence, big data, the Internet of Things, and cybersecurity with electrical engineering teaching. The continuous advancement of the industry-university collaborative education model brings real-world engineering projects, case studies, and the latest technologies from enterprises into the classroom, allowing students to access the latest trends in industry development while still in school and learn practical skills and engineering thinking. To more intuitively reflect the differences in energy-saving effectiveness of smart electricity management under different application scenarios, a comparative analysis of the energy-saving rates for each scenario is presented, as shown in Figure 2.

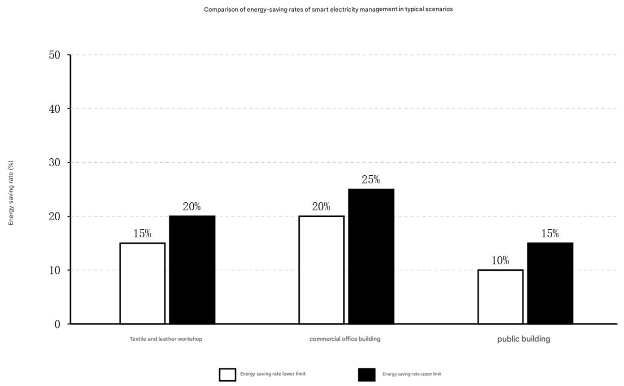

Fig. 2. Comparison of Energy-Saving Rates in Typical Smart Electricity Management Scenarios.

V. CONCLUSION

The intelligent integration of power systems is an inevitable result and a choice of our times, stemming from the deep integration of information technology and energy. It has transformed the traditional power industry's development and industrial structure at an unprecedented speed and depth. From the widespread deployment of intelligent sensors, the comprehensive construction of the Internet of Things architecture, the deep application of artificial intelligence algorithms, and the integration of digital twins with the real world, the level of intelligent power systems is constantly making new progress and reaching new heights. Faced with increasingly serious cybersecurity threats, an incomplete standards system, and a lack of interdisciplinary talent, only by adhering to a combination of technological and management innovation, a combination of standards development and talent cultivation, and a combination of security assurance and open sharing can the intelligent integration of power systems develop in a healthy and orderly manner.

REFERENCES

[1] R. Li, T. Tian, F. Ji, et al., "Application and prospect of image processing technology in tomato growth monitoring," Chinese Journal of Agricultural Mechanization, vol. 46, no. 11, pp. 74–82, 2025.

[2] F. Chen, Z. Luo, Y. Zhao, et al., "Reconstruction of the knowledge structure of land science in the era of artificial intelligence," Chinese Land Science, vol. 39, no. 12, pp. 9–19, 2025.

[3] H. Liang, J. Sun, Y. Fan, et al., “Design and application of Internet of Things solution for medical equipment in intensive care unit,” Journal of Biomedical Engineering, vol. 42, no. 1, pp. 65–72, 2025.

[4] K. Si, “Application and challenges of digital design in chemical machinery,” Plastics Industry, vol. 52, no. 11, pp. 177–178, 2024.

[5] Y. Zhang, T. Nie, Y. Chen, et al., “Design of fault diagnosis system for reciprocating compressor based on digital twin technology,” Chemical Equipment & Pipeline, vol. 62, no. 5, pp. 50–58, 2025.

[6] Z. Pan, G. Pan, P. Wang, et al., “Exploration and practice of intelligent steelmaking under the guidance of metallurgical process engineering theory,” Iron and Steel, vol. 60, no. 7, pp. 83–90, 2025.

[7] B. Zhang, X. Cao, T. Zhou, et al., “Discussion on the current status and development trend of drilling equipment technology for deep and ultra-deep wells,” Drilling and Production Technology, vol. 47, no. 2, pp. 141–151, 2024.

[8] P. Yao and J. Yu, “Design and practice of unmanned surface vessel simulation teaching platform for autonomous intelligent systems,” Laboratory Research and Exploration, vol. 44, no. 9, pp. 128–134, 2025.

[9] P. Han, E. Hu, C. Wang, et al., “Research on the construction of intelligent power supply data application standards in mines,” China Coal, vol. 50, no. 6, pp. 90–97, 2024.

[10] J. Yao, Z. Zhang, Y. Tang, et al., “Research progress on material preparation based on gas-solid two-phase flow principle,” Solid Rocket Technology, vol. 48, no. 6, pp. 807–817, 2025.

[11] Y. Sun, Y. Wang, D. Wei, et al., “Research on the construction of a TCM intelligent auxiliary diagnosis and treatment system based on digital twin technology,” Chinese Journal of Traditional Chinese Medicine, vol. 42, no. 9, pp. 18–22, 2024.

[12] W. Wu, Z. Zheng, H. Wang, et al., “Research on swarm intelligence and industrial cluster development strategy,” Chinese Engineering Science, vol. 26, no. 1, pp. 89–100, 2024.

[13] K. Lei, H. Zhang, H. Qiu, et al., “Construction and application of smart national park technology system,” Science of Forestry, vol. 61, no. 10, pp. 15–25, 2025.

[14] G. Zhong, G. Jiang, W. Chen, et al., “Construction of smart power plants driven by artificial intelligence - technology review and frontier prospect,” Clean Coal Technology, vol. 32, no. 2, pp. 25–41, 2026.

[15] W. Zhou, Y. Lu, W. Sun, et al., “Analysis on the current status and future trends of international polar ship technology development,” Shipbuilding Engineering, vol. 48, no. 1, pp. 41–54, 2026.