Research on Key Issues of Digital Transformation of New Type Power System

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Abstract. This article systematically examines the construction background and future development trends of the New Type Power System. By considering major technological challenges, it analyzes the pivotal role of digitalization in advancing low-carbon development in power, fostering market-oriented reforms, upgrading industrial chains, and modernizing supervision. Furthermore, it delves into the application scenarios and critical issues associated with digital technologies in energy production, consumption, institutional frameworks, and technological advancements. This provides valuable insights for China's power industry to proactively engage in the new round of technological and industrial revolutions, thereby accelerating its digitalization and intelligent upgrading.

Keywords: digital technologies, power system, low-carbon

1 Introduction

For nearly a century, as global climate change intensifies and existing energy sources are increasingly depleted, an increasing number of countries are making net zero pledges. The power system will become the main link in energy supply, consumption, and transmission conversion, requiring support for the consumption of clean energy, ensuring the diverse energy needs of end-users, and forming a modern energy system hub and platform that can support the cross conversion of multiple energies. On July 11, 2023, China proposed that it is necessary to deepen the reform of the power system, accelerate the construction of the new type power system that is clean, low-carbon, safe, economically efficient, flexible and intelligent power system.

Developed countries such as the United States, the United Kingdom, and the European Union continue to promote low-carbon energy transformation and power system reform under government leadership, and have made a series of progress in renewable energy resources generation and grid connection. In the United States, where the electric power sector is currently the second-largest producer of emissions, policy makers set a goal to reach a 100% carbon pollution-free electricity system by 2035 [1-2]. Another example is the European Union, where the European Commission has presented the REPowerEU Plan to replace fossil fuels in homes, businesses, and power plants as quickly as possible in order to reduce the reliance on Russian fossil resources [3]. Japan

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is the earliest Asian country to conduct research on renewable energy resources systems. Japan plans to achieve a renewable energy generation target of 36% to 38% by 2030. They all adopt digital technology as a key to drive the development of power systems and achieve zero-carbon emission targets.

2 The Role of Digital Technologies in the Transformation of the Power System

2.1 Digitization Drives the Low-Carbon Development of the Power System

Digitization can effectively assist in accelerating clean energy production. Renewable energy resources, such as wind and PV, continues to develop rapidly and is mainly utilized through conversion into electricity. It is expected that by 2030, the installed capacity of wind and solar power will surpass coal-fired power and become the largest power source. However, the inherent randomness, volatility, and uncertainty of renewable energy resources sources will bring many risks to the balance of power generation and safe and stable operation of the power system. In this context, the widespread application of digital technologies can achieve comprehensive monitoring of the electrical, state, physical, environmental, spatial, and behavioral quantities of massive renewable energy resources equipment. Through big data analysis and intelligent decision-making, it can effectively improve the accuracy of renewable energy resources generation output prediction, and ensure the safe and stable operation of the power system. At the same time, using digital technologies to build industrial Internet platforms such as renewable energy resources cloud can also effectively promote scientific planning, rational development, efficient construction, safe operation and full consumption of renewable energy resources power generation through scientific analysis and rational use of renewable energy resources power generation data.

Digitization can effectively assist in highly electrified energy consumption [4]. Electricity is a clean and efficient secondary energy source. It is expected that by 2030, the proportion of electricity in China's terminal energy consumption will increase from 27% in 2020 to over 35%. At the same time, the energy demand of power users has also shown a trend of diversified, intelligent, and interactive development. The widespread application of digital technologies can achieve extensive interaction, full sharing, and value mining of end-user data. The smart car networking platform is a typical case of digital technologies promoting highly electrified energy consumption. At present, State Grid Corporation of China has built the world's largest smart car networking platform with the largest number of connected charging stations and the widest coverage area. It has accumulated over 1 million connected charging stations and served nearly 6 million electric vehicle users, achieving one click finding and smart charging for electric vehicle owners. At the same time, relying on the innovative green electricity trading mechanism of the smart car networking platform, State Grid Corporation of China has effectively promoted the use of clean and green electricity from Qinghai, Gansu and other places by car owners in pilot cities such as Beijing, Zhejiang and Chongqing.

Digitization can effectively assist in the increasingly efficient utilization of energy. With the continuous increase of energy conservation, emission reduction and consumption reduction efforts, the comprehensive utilization efficiency of energy is gradually improving. The power grid connects energy production and consumption, serving as a hub platform for energy conversion, utilization, and transmission configuration. Its role in promoting the interconnection, efficient allocation, and comprehensive utilization of various types of energy is becoming increasingly prominent. It can also give play to the amplification, superposition and multiplication effects of energy data elements, support the upgrading of the power grid to the energy internet, and realize the multi energy complementation and efficient utilization of electric heating, cold air and hydrogen [5].

2.2 Digitization Supports the Market-Oriented Transformation of Electricity

Digitization gives rise to emerging market entities. The development of digital technologies has made it possible for bidirectional interaction between power system loads and power sources, as well as demand side intelligent control, greatly promoting the development of distributed energy grid integration and consumption technologies, demand response technologies, energy storage technologies, electric vehicles, and other technologies. Relying on digital information communication and Internet technologies, all kinds of decentralized, sleeping and adjustable resources of all elements of "source network load storage" are aggregated [6]. By virtual power plants, it widely gathers demand side resources such as adjustable industrial and commercial, smart buildings, and EV charging stations, to achieve flexible interaction among various entities [7].

Digitization can help improve the transparency of the electricity market. With the rapid increase in the number of market entities and market-oriented trading volume, as well as the continuous enrichment of electricity trading varieties, a large amount of market data such as forecasting, declaration, clearing, and settlement needs to be timely and accurately disclosed to market entities. The electricity market information disclosure platform relies on digital technologies to obtain data in bulk through system docking, achieving intelligent and automated information disclosure.

Digitization can help with green electricity trading. Blockchain technologies has the characteristics of distributed high redundancy storage, difficult tampering and forgery of time-series data, and decentralized credit. The green electricity trading platform adopts blockchain technologies to comprehensively record information in various aspects of green electricity production, trading, transmission, consumption, settlement, etc., fully utilizing the characteristics of blockchain multi-point consensus, tamper proof, traceability, etc.. To provide important support for the connection between the green electricity market and the carbon market, green certificate subscription, and renewable energy consumption responsibility weighting policies in the future, and to establish a unified national green electricity certification system.

Digitization can serve the modernization of market regulation. Electric power big data contains a large amount of information, and strong implementation accuracy. Advanced technologies such as big data provide new tools and means for regulation. Relying on power big data and digital platforms to provide market supervision information

to regulatory agencies, exploring the establishment of data interfaces with relevant regulatory agencies, achieving real-time sharing of data required for supervision, and fully leveraging the regulatory value of power big data.

2.3 Digitalization Helps Upgrade the Power Industry Chain

Digitization can empower the industrial ecosystem and promote the interconnection and sharing of the power industry chain. The cooperation among enterprises in the traditional power industry chain is fixed and the mode is single. As the ecological platform of the power industry chain, the digitalization of the Energy Internet plays a key role in its construction process. It is the foundation for creating value in the power industry chain. "Sharing" is the spirit of the energy Internet. It realizes the digitalization and transparency of energy resources through the information layer, and opens the data to producers and consumers, revitalizing and optimizing energy resources.

Digitization can empower reform and development. The core of digital empowerment is to "reduce costs and improve efficiency". Digital technologies such as 5G and the Internet of Things drive enterprises in the power industry chain to achieve larger scale data asset sharing and reuse, and enhance the international competitiveness of China's power industry. As a typical case of digitalization helping to reduce costs and improve efficiency in the power industry chain, the integrated energy system integrates the supply and demand sides of the power industry chain, with smart energy efficiency management cloud platform.

Digital empowerment for risk prevention and control, ensuring the safety and reliability of the power industry chain. Energy security is a global and strategic issue related to the economic and social development of a country. The coordination chain of the power industry chain is long, and the degree of cross industry information integration is poor. The safety warning system relies on advanced measurement systems and communication networks to collect data and transmit safety warning information. It is even more necessary to empower risk prevention and control through digitization and improve the risk warning system of the power industry chain.

3 Conclusion

Overall, digital technologies will be deeply applied in various fields such as energy production, consumption, system, and technologies, and it is also a key area and important lever for open cooperation in power. Advancing the digital and intelligent transformation and upgrading of power is an urgent choice for fully, accurately, and comprehensively implementing the new development concept. At the same time, the digital and intelligent transformation and upgrading of power can effectively promote the power data connection of the entire energy production, transmission, storage, trading, and consumption chain, promote supply and demand docking, factor restructuring, integration innovation, enhance industrial coordination, lean management, and intelligent service capabilities, and provide unprecedented development opportunities for the transformation and development of China's power industry.

From the vantage point of future development trends, the evolution towards energy digitalization and intellectualization encompasses both "intelligence+" advanced technological innovation and "energy+" advanced business model innovation. This transformation will give rise to advanced energy system forms such as the new energy system and energy internet, serving as a quintessential manifestation of the digitalization and digital industrialization within the energy sector.

Firstly, in terms of technology, the integration of advanced "intelligence+" technologies serves as a catalyst for the digitization of the energy industry. Technologies like "Big Data, Cloud Computing, IoT, Smart Systems, and Blockchain" (collectively referred to as "Intelligence Plus") are strategic pillars driving a new wave of technological and industrial revolutions. The trajectory of energy digitization and intellectualization hinges on "intelligence+" technologies, fostering a technology ecosystem that deeply integrates advanced information and communication technology, intelligent control technology, and cutting-edge energy technology. This integration propels comprehensive upgrades in energy technologies, spanning multi-energy conversion and utilization, coordinated operation and control, and flexible response and interaction mechanisms. By tapping into diverse application scenarios, "Intelligence Plus" technologies will be pervasively applied across energy production, transmission, consumption, and trading, ensuring comprehensive observability, precision measurement, intelligent control, and flexibility in adjustment across all facets of the energy landscape, thereby effectively catalyzing the transformation and advancement of the energy system.

Secondly, in terms of functionality, the innovation of advanced "energy+" business models propels the digital industrialization of energy. China's digital economy is continually deepening, emerging as a pivotal engine driving the nation's economic growth. Within the energy industry, a thorough exploration of the value embedded in data resources across energy production, transmission, consumption, and trading can harness the amplification, superposition, and multiplicative effects of energy data elements. This can facilitate cross-temporal and spatial energy optimization, cross-category energy conversion and collaborative management, and cross-entity energy trading, ultimately enhancing production quality, operational efficiency, service upgrades, and data value-addition within the energy system, thereby giving birth to advanced "energy+" business models. The digitalization and intellectual development of energy leverages the advanced "energy+" business model as a conduit to foster a system of friendly interactions and efficient resource allocation among stakeholders. This system effectively supports the large-scale development and utilization of renewable energy, enabling the "plug and play" functionality of various energy facilities. It also enhances the coordination and interaction among "source, grid, load, and storage," ensuring personalized, comprehensive, and intelligent energy services, thereby fostering green and sustainable development across society.

Thirdly, the formation of a new energy system and energy internet is anchored in new energy infrastructure. The digital and intellectual development of energy leverages this infrastructure as its physical foundation, giving rise to a robust and widely distributed new energy system and energy internet. This system encompasses centralized and distributed energy systems, diverse energy storage facilities, and user-friendly inter-

connections, fostering interconnectedness among various energy systems. The new energy system and energy internet encompass not only "point" upgrades such as distributed smart energy, smart mines, smart power plants, and smart buildings, but also "network" interconnections via smart grids, smart pipe networks, smart heating networks, and intelligent transportation networks. Additionally, it involves the construction of "platforms" encompassing data centers, business hubs, dispatching centers, and trading centers. The diverse components of the new energy system are organically interconnected, efficiently coordinated, mutually reinforcing, and empowering, ultimately achieving systematic advancement in energy digitization and intellectual development.

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