Research on Key Technologies Framework for Digitalization Empowering New Power System Operations

Yuliang He[1a], Xiaoman Qi[2b], Lian Liu[3c], Yuxin Zhang[4d*], Xinyu Chen[5e]

{hylvenn@hust.edu.cn[a], qixiaoman79@126.com[b], liankid@163.com[c], zyx20@hust.edu.cn[d*], xchen2019@hust.edu.cn[e]}

Huazhong University of Science and Technology, School of Electrical and Electronic Engineering, Wuhan 430074, China[1,4*,5]
State Grid Shanghai Municipal Electric Power CO, Shanghai 200122, China[2,3]

Abstract: As the main battlefield for decarbonization and emission reduction, the power industry will fully support the national-level transition of the energy system, mainly utilizing renewable sources. Nonetheless, the evolution of the new power system will significantly exacerbate the disparity between power supply and demand on both spatial and temporal scales. Therefore, it is imperative to enhance the fundamental capacity of the power grid to ensure optimal allocation of resources across a wider range and at a higher frequency, and to facilitate the interaction between the system, nature, and human society through precise grid dispatch and efficient market transaction. Such a large-scale, high-frequency, multi-level coupling relies extensively on the essential support of new generation of digital technology, such as big data, cloud computing, IoT, mobile internet, AI, and blockchain. Based on the inherent characteristics of the new power system, this paper explores the mechanism of digital empowerment on the new power system. With focusing on the significant demand for digital technology in the system operations, we propose certain typical scenarios of digital empowerment of the new power system, and build a framework of digital dispatch and transaction, with a view to providing theoretical references for the construction of China's new power system.

Keywords: new power system; power grid operation; digital technology; data-driven

1 Introduction

Since the ambitious goal of carbon peaking and carbon neutrality was proposed, China's energy system has steadily stepped into a transition towards a new era of low carbon emission. Served as the main force of decarbonization and emission reduction in the energy sector, the new power system will fully support the national energy transition. The new power system is significantly different from the traditional power network, mainly embodied in the following four transformations: from a high emission industry to a low-carbon/zero-carbon one; from a mechanical electromagnetic system to an electronics-based one; from the deterministic, controllable, and continuous power supply to an uncertain random fluctuation one; from a high rotational inertia system to a weak rotational inertia one.

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Specifically, the transformation owns significant trends in all aspects.

(i) As for the "source", the existing energy structure will undergo a significant transformation, as well as the role of each type of power unit. Installed capacity of renewables continues to expand, and clean energy units will assume the role of the main power supply, while thermal power units gradually transformed into the likes of regulatory and standby power. The overall production becomes intermittent, fluctuating, and uncertain, with the spatial distribution of power supplies tending to be decentralized, and the power electronic devices penetrating rapidly.

(ii) As for the "gird", the main grid interconnect further between provinces, while distributed microgrid control technology breakthroughs are expected to support the optimization of the active distribution network, the distribution network will gradually evolve into an active power supply network. Ultimately, it is presented in the form of a flexible and controllable "main network + active distribution network + microgrid". In addition, the power grid will be gradually transformed from a pure electricity transmission channel to a comprehensive multi-energy platform, deeply coupled with other energy systems such as heat network, natural gas pipeline, hydrogen and ammonia derivatives production, transportation, etc.

(iii) As for the "load", the electrification process is inevitable, and the overall elasticity of the consumption is expected to be significantly improved. With the steady increase of the installed capacity of distributed power, the wide access of adjustable loads such as electric vehicles and smart buildings, the promotion of demand-side response mechanism and the development of virtual power plants, numerous "prosumers" will actively participate in market transactions and system regulation. The traditional "source follows load" mode will surely become a brand-new one of "source-load interaction".

(iv) As for the "storage", high-efficiency, low cost, large scale and multi-functionality are the core features of storages under the new power system. In the short term, pumped storage and electrochemical energy storage develop. The category will be further diversified in the long term, achieving the optimization of the convergence of regulation and operation in the multidimensional timescale, and to become an important role in improving the flexibility, stability, and reliability of the power system. The scale of energy storage will grow at the same frequency with the expansion of renewable energy capacity, suppressing random fluctuations and effectively promoting renewables integration.

Under the new power system, the mismatch between power supply and demand will be further intensified on multidimensional spatial and temporal scales. There is an urgent need to improve the core ability of the system to realize the optimal allocation of resources, in order to support the interaction between the system, nature, and human society through precise grid dispatch and efficient market transaction. Such a large-scale, high-frequency, multi-level coupling relies extensively on the essential support of new generation of digital technology, such as big data, cloud computing, IoT, mobile internet, AI, and blockchain. In recent years, digital technology has been playing a significant role in various aspects of the power system, and numerous scholars worldwide have put forward their concepts and scenarios for the integration of digital technologies and the new power system. Based on the background of the digital transformation of power system, the literature [1] summarized the current development status and future research direction of certain aspects of advanced sensor technology, intelligent analysis, and operation control of power grid; the literature [2] summarized the application of digital twin technology in the power system, and introduced the general process of digital twin construction; the literature [3] analysed the relationship between big data, cloud computing and smart grid, then discussed the overall architecture of the electric big data platform from certain perspectives; the literature [4] summarized the characteristics of big data in distribution networks, and took distribution network load forecasting, operational status assessment, power quality monitoring and assessment, distribution network optimization, etc. as examples; the literature [5] sorted out the applications of artificial intelligence in renewables prediction, load prediction, malfunction diagnosis, on-line stability assessment in power system operations; the literature [6] analyzed development prospects of the energy Internet, and discusses the main challenges that may be faced in the construction process of the energy Internet in view of the core issues such as coordination and control of distributed devices, integration of power system with transportation system and natural gas network, information physical modelling and security; the literature [7] compiled the key technologies and their main features in energy Internet, analyzed the positioning function of smart grid in energy Internet system, and further discussed the development mode of energy Internet; the literature [8] summarized the transformation of energy system under the goal of carbon neutrality, and introduced the multi-functional energy system under the background of high proportion of renewable energy,then designed the multi-energy market mechanism to support the new energy grid connection; the literature [9] comb through the application scenarios of blockchain in the energy system, and elaborated the role of blockchain in the links of metering and authentication, synergistic organization, and market transaction; the literature [10] refined the theoretical research on the blockchain technology in the electricity transaction, and summed up the role of blockchain technology in distributed energy trading, property right registration, information sharing and other aspects of the application status quo; the literature [11] studies the existing architecture, application scenarios and future challenges of IoT technology in smart grid. Literature [12] sorted out the application prospects and technical advantages of blockchain technology in smart grid, and put forward the key application framework of smart grid based on blockchain. The literature [13] deeply analyzed the underlying logic of big data technology, described the application prospects of big data analysis in the context of smart grid, and discussed the challenges and opportunities brought by the empowerment of artificial intelligence algorithms, such as machine learning, and big data in smart grid.

Under the carbon-neutral transition, there are two significant transformation trends: the substitution of renewable energy sources for traditional fossil energy sources, and the substitution of electrical terminal equipment for other energy-use ones. Therefore, the randomness, volatility, and unpredictability on both sides of the supply and demand will be greatly aggravated, with the rotational inertia of the grid nodes will be significantly weakened, the system security and stable operation will be subject to multiple risks and challenges. Enhancing the observability of this high-dimensional, time-varying, nonlinear physics system, then constructing its describability and ensuring its controllability, is the primary objective of the transition empowered by digitization. In this paper, we first designed the overall framework of the digital technologies empowering power system, and put forward the core scenarios of digital technology applications in the new power system. Subsequently, based on the new operating characteristics, we build the technical architecture of the regulation and transaction empowered by digitization, with a view to providing theoretical references for the transition of the new power system operations.

2 Key digital technologies and core application scenarios for digitalization empowering new power system

2.1 Overall empowerment framework

Digitalization, informatization, intelligence, and interaction are the key features of the power system transition, which can be specifically presented as followed: the deep integration of the new generation of digital technology and the new generation of electric power technology; the deep integration of the virtual digital space and the real physical system. The overall framework of the new power system empowered by digital technology is shown in Fig. 1 below.

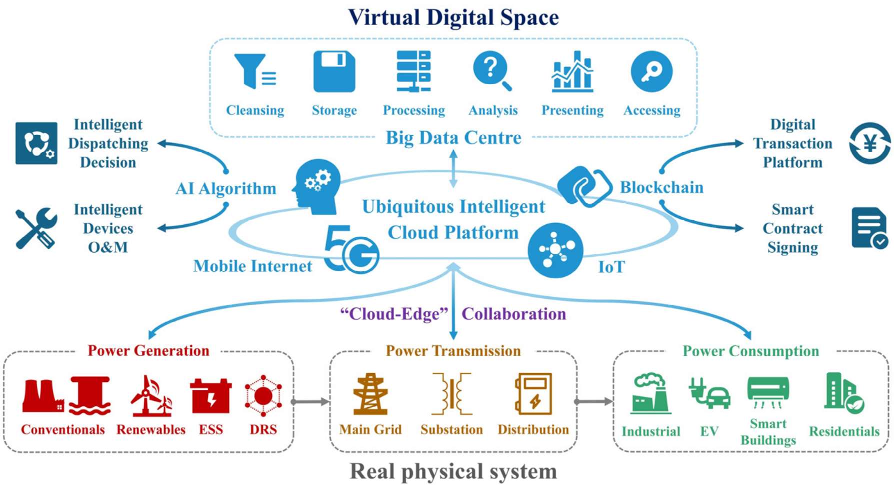

Fig. 1 Overall framework of digital technologies empowering new power systems

The real physical system covers numerous power equipment at the edge layer, realizing real-time data collection through the deployment of panoramic intelligent sensors. With mobile communication network deployed, the interoperability and interconnection between power equipments can be realized, and synergistic operation with intelligent cloud platform in the mode of convergence of "cloud-edge synergy" will be achieved. At the same time, the big data centre undergoes cleaning, storing, processing, analysing, presenting and accessing of real system data, realizing the quantitative analysis of the dynamic characteristics of the main subjects of the new electric power system, and providing a data basis for other digital technology applications. In addition, the empowerment of digital technologies relies on the basis of the ubiquitous intelligent cloud platform, which can provide elastic and expandable computing space to integrate other applications. It can support artificial intelligence, blockchain, and other digital technologies to realize core application functions such as intelligent regulation, intelligent operation and equipment maintenance, distributed transactions and signing of smart contracts, which significantly enhances the empowerment for electric power data elements and digital technology elements.

2.2 Core application scenarios

Based on the overall framework of digital technologies empowering new power systems,we further propose certain core application scenarios in the digitalized new power system, as shown in Fig. 2.

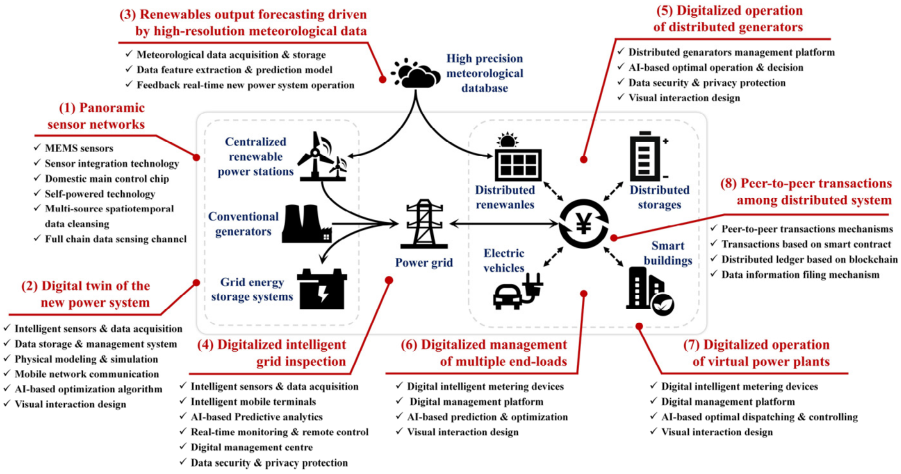

Fig. 2 Core application scenarios in the digitalized new power system

2.2.1 Panoramic sensor networks

Realizing the extensive collection and real-time transmission of data elements in all segments of the new power system is a prerequisite for ensuring the observability of the new power system and supporting digital empowerment. Gaining information about the power system requires the extensive integration of the panoramic sensors into the entire lifecycle of electric power. Firstly, intelligent sensors should be widely deployed to measure key technical data such as voltage, current, magnetic field, frequency, rotational speed and others, to realize real-time monitoring, operation status diagnosis, and effectively improve the observability of the system and its equipments; secondly, technologies like artificial intelligence and big data analysis should be utilized to support the simulation and optimization, and provide scientific decision-making for the optimization and regulation of the new power system. The specific architecture and technical composition are shown in Fig. 3.

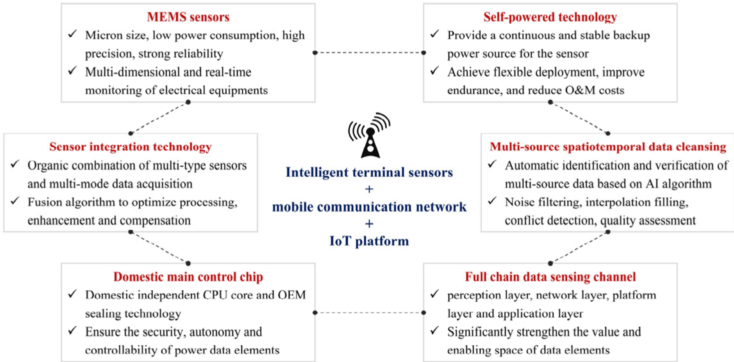

Fig. 3 Panoramic sensor networks

2.2.2 Digital twin of the new power system

The new power system has the characteristics of "high proportion of renewable energy + high proportion of power electronic devices + high proportion of distributed energy". Its operation mechanism has undergone a major transition, while the traditional physical model, control theory and analysis methods are incapable of satisfying regulation, operation, planning, etc. It is urgent to update the tools of system simulation analysis.

The construction of a digital twin of the new power system can significantly improve the observability, describability, and controllability, and is an important approach to promote the digital development of the power grid. Digital twin refers to the establishment of a digital mapping model of the power system in the computer environment using sensing data and digital technology, to achieve a comprehensive perception of the power grid and real-time monitoring. Its characteristics are: autonomy, synchronization, interaction, symbiosis. Through the construction of a digital twin, on the one hand, a two-way data transmission mechanism between the physical entity and the digital twin can be established, ensuring their interaction and synchronization in the whole lifecycle, being able to realize multiple functions of data transmission, state perception, behaviour tracking, trend analysis and intelligent decision-making; on the other hand, based on the self-evolutionary algorithms of the digital twin, it can strongly support the optimized operation, equipment management, environmental monitoring, troubleshooting, and other core functions of the new power system through virtual simulation analysis and probabilistic scenario prediction. The specific architecture and technical composition are shown in Fig. 4.

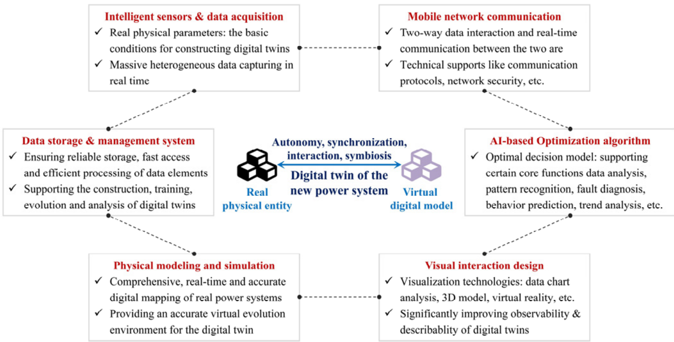

Fig. 4 Digital twin of the new power system

2.2.3 Renewables output forecasting driven by high-resolution meteorological data

Under the carbon-neutral transition, renewable generators will gradually become the main power supply, yet its intermittency, high volatility, strong randomness, unpredictability, and other inherent characteristics will hold a significant impact on the system-wide power balance. The real-time operation of the system under the high penetration of renewables faces serious challenges. Meteorological conditions are the key constraints of renewables such as wind turbines and photovoltaic units, the output characteristics are completely dependent on the spatial and temporal heterogeneous characteristics of wind and solar power: relatively abundant sunshine in the daytime while wind energy at night; relatively abundant solar resources in the summer while wind resources in the winter. The mode of renewable energy output under multi-temporal and spatial scales has already become an important influencing factor for the regulation and transaction in new power system.

Therefore, it is necessary to build an efficient and accurate prediction model of renewables output based on high-precision meteorological data on multi-temporal and spatial scales, combined with a new generation of digital technologies such as big data analysis and artificial intelligence algorithms, to predict the output curve of renewable energy units and provide scientific support for real-time operation of the system, which can significantly improve observability and describability of the generation side. It is an important application scenario under a high proportion of renewable energy and distributed generators. The specific architecture and technical composition are shown in Fig. 5.

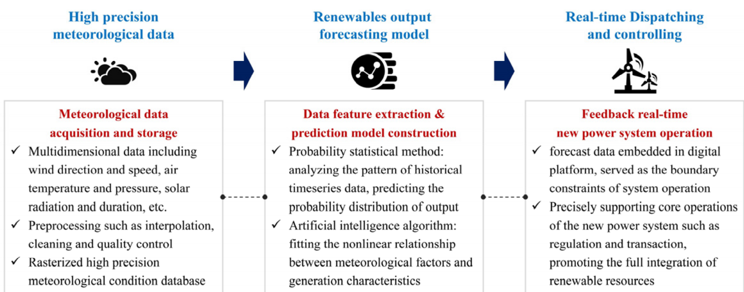

Fig. 5 Renewables output forecasting driven by high-resolution meteorological data

2.2.4 Digitalized intelligent grid inspection

Inspection contributes to enhancing the reliability and durability of transmission, substation, and distribution equipment, to ensure the stability of the power grid operation. It is one of the vital obligations of power grid enterprises. In recent years, China's installed capacity of generators and end-use power equipment scale stable and continuous growth, with significant grid equipment outgrowth subsequently. However, the traditional manual inspection exposes heavy workloads, high labour costs, and vital security risks, leading to low efficiency and numerous drawbacks. The conventional method seems difficult to undertake all-weather, real-time monitoring and O&M tasks.

Utilizing digital technologies is a highly efficient and economical solution to realize the inspection of power transmission, substation, and distribution equipments. Digitalized intelligent inspection takes robots, drones, and other mobile terminals as the technical carrier, and relies on the accurate identification and intelligent analysis of artificial intelligence technology to monitor, analyse, evaluate and warn the operating status and environmental conditions of electrical equipment, which can significantly improve the accuracy and efficiency of inspection tasks. It is an important approach to improve the stability of power system operation while promoting grid enterprises to reduce costs and increase efficiency. The specific architecture and technical composition are shown in Fig. 6.

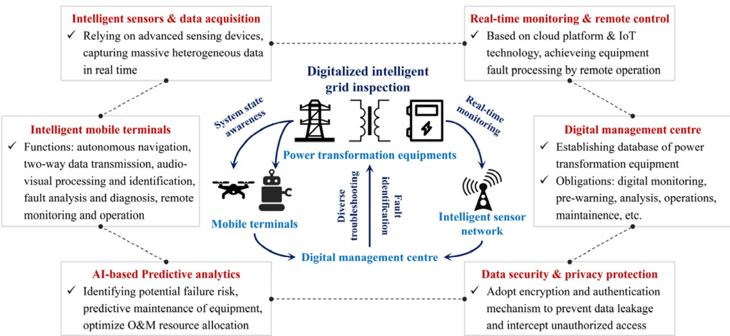

Fig. 6 Digitalized intelligent grid inspection

2.2.5 Digitalized operation of distributed generators

Optimal aggregation and cost-effective integration of distributed renewable resources to achieve decarbonization of production is a key approach to support carbon-neutral transition of the new power system. In the future, numerous distributed generators, such as wind power, photovoltaic, and storage, will be widely accessed to the microgrid. However, their operation modes are of great autonomy and randomness, which will bring systematic risks to the real-time power balance of microgrid. There is an urgent need to integrate certain digital technologies to realize the digital operation of distributed power. Firstly, in order to achieve the strong real-time, high-frequency flexible regulation between the centralized grid and distributed equipments, it is necessary to deploy a low-latency, high-speed, wide-connectivity 5G mobile communication network, opening up the real-time bidirectional transmission channel between the main network and the micro-network. Secondly, it is necessary to widely deploy intelligent sensors and form a communication and transmission network in the edge equipment to capture, analyse, present and manage key data such as output curve, regulation status, environmental information, O&M data, then realize real-time sensing and precise regulation of massive distributed equipments, which can significantly improve the observability and controllability of distributed power system, effectively promote the maximum integration of distributed renewable energy, and actively support the economic scheduling and stable operation of microgrid system. The specific architecture and technical composition are shown in Fig. 7.

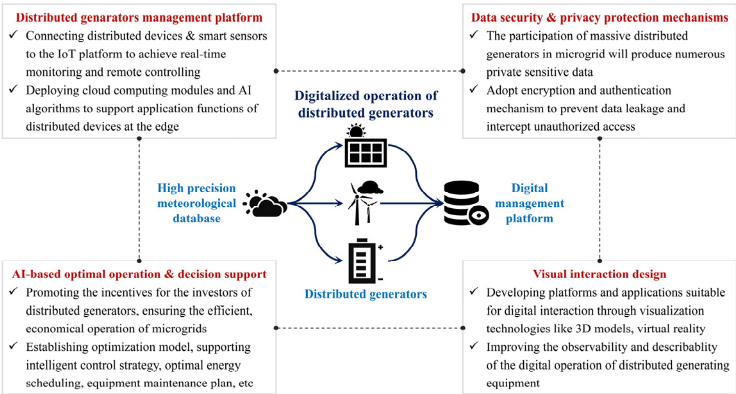

Fig. 7 Digitalized Operation of Distributed Generators

2.2.6 Digitalized management of multiple end-loads

Terminal electrification substitution is an inherent feature of the demand side. With the broad access of user-side storage stations, electric vehicles, intelligent buildings and other adjustable loads to the system, the ramping rate and peak-regulating capability of the demand side will be significantly improved. The traditional "source follows load" dispatch mode will be transformed into a new mode of "source-load interaction". Under the incentive-compatible market mechanism, through the scientific coordination of multiple terminal loads, the huge response potential of adjustable loads such as electric vehicles and smart buildings will be released, which can effectively alleviate the regional power imbalance on an intraday scale due to the high volatility, strong randomness, and intermittency of high proportions of renewables.

Firstly, a digital management platform should be established in the microgrid, linked to smart meters and other digital metering equipment, to realize the collection, analysis, and presentation of multi-terminal load status information and operation data. Secondly, intelligent regulation algorithms for multiple terminal loads should be deployed to realize decision-making and integrated regulation of multiple adjustable loads, on the basis of distributed renewables output forecast, node marginal price and other data elements, which will significantly improve the controllability of large quantities of multiple terminal loads, supporting stable and economic operation in microgrids. The specific architecture and technical composition are shown in Fig. 8.

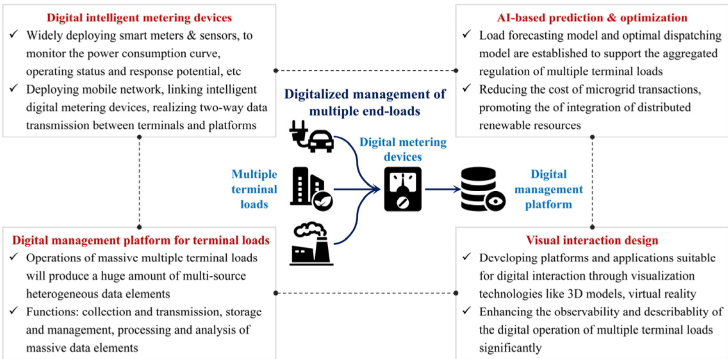

Fig. 8 Digitalized management of multiple end-loads

2.2.7 Digitalized operation of virtual power plants

In the traditional mode, centralized generating units are the main objects of system dispatch. The system operator forecasts the overall demand, takes the load curve, renewables output, transmission constraints, etc. as the boundaries, and then optimizes the output curve of each dispatchable by using the unit commitment and the economic dispatching algorithm. Under the new power system, numerous distributed generators on the supply side and the diversified terminal loads on the demand side will be widely connected to the microgrid, and the number of dispatch objects will increase dramatically and be distributed widely.

Virtual power plant is a new type of power system management concept, relying on advanced information technology, communication technology and intelligent algorithms and adopting flexible control methods, integrates geographically dispersed distributed generators and diversified adjustable loads into a unified virtual system. Then, it realizes the monitoring and controlling of dispersed electric resources, and prioritizes the aggregation optimization and decision-making scheduling inside the virtual system, further supporting dispatch and transaction in microgrid. The digitalized operation of virtual power plant can effectively broaden the elasticity of distributed system, improve the utility of regulation and efficiency of energy utilization, and significantly enhance the controllability of distributed system, which is an important scenario application to support the main-micro grid coordinated operation. The specific architecture and technical composition are shown in Fig. 9.

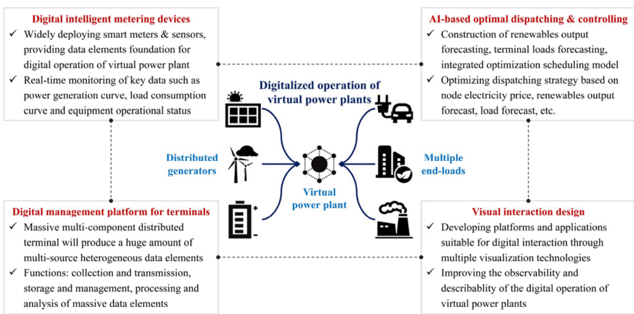

Fig. 9 Digitalized operation of virtual power plants

2.2.8 Peer-to-peer transactions among distributed system based on blockchain

The clearance of energy transaction in microgrid directly determines the system dispatch operation. Centralized transaction mode has a series of drawbacks such as high transaction cost, settlement difficulty, complex process and information asymmetry in point-to-point transaction among distributed system, which to a certain extent weakens the incentive for long-term investment in distributed resources, therefore hampers the rapid penetration of distributed renewables and diversified end-use loads. Constructing a high-efficiency, low-threshold, and widely-connected trading mode is a prerequisite for improving the operation efficiency in microgrid.

The promotion of the "selling through the wall" policy will form a new distributed peer-to-peer transaction architecture, therefore the energy transaction in microgrid should also adopt a distributed mechanism that combines economy and security. Hence, blockchain technology should be fully utilized to establish a distributed peer-to-peer transaction platform for the supply and demand objects in microgrid, making full use of the technological advantages of decentralization, openness, transparency, forgery, and traceability. This can significantly reduce the threshold and lower the cost of transactions in microgrids, greatly promoting the enthusiasm of new objects to participate in microgrid operation. The specific architecture and technical composition are shown in Fig. 10.

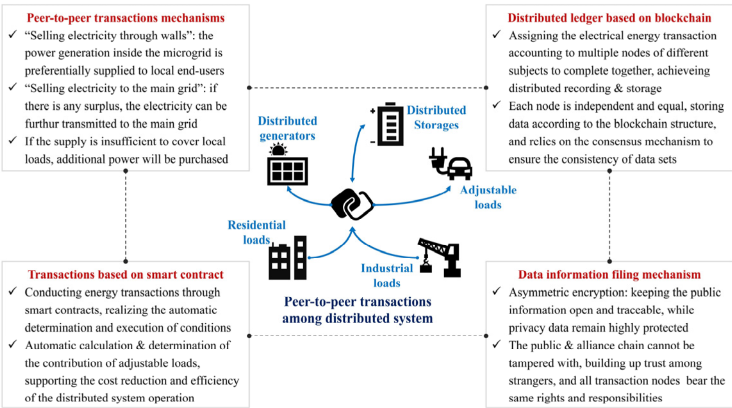

Fig. 10 Peer-to-peer transactions among distributed system based on blockchain

3 Technical architecture of the regulation and transaction empowered by digitization

The new power system has a significant transformation trend in all perspectives of sources, grids, loads, and storages. Current regulation and transaction structure seems difficult to adapt to the increasingly complex physical system in the future, mainly reflected in the following aspects: (i) Insufficient precision of regulation and transaction. Operations in the future not only concentrate on the main grid, a mass of distributed objects will also be widely involved. An efficient and economical operation approach can fully stimulate the interconnection among distributed generators and adjustable loads, which can significantly reduce the cost of electricity consumers. However, there is no application example of coordinated operation between microgrid and main grid, so there is an urgent need to improve the overall accuracy of dispatch and trading. (ii) Doubtful capability of data processing. With the widespread popularization of distributed power sources and diversified end loads, the volume of data faced by the system operation will grow exponentially. Meanwhile, for the adjustable demand of electric vehicles, industrial loads and smart buildings, the operator needs to combine meteorological conditions, real-time data from the supply side, and physical constraints of the transmission and distribution network to utilize optimization algorithms, then give instructions to the corresponding end-users. However, it has not yet been demonstrated whether the existing system can adapt to the big data scenarios in terms of data reception, data analysis and regulation arithmetic. (iii) Dynamic characteristics need to be strengthened urgently. The significant enhancement of volatility has put forward higher requirements for the dynamic characteristics of system regulation and transaction. The current minimum timescale of real-time grid scheduling is 15 minutes, which is difficult to cope with the volatility and uncertainty at the minute or even second level under the scenario of a high proportion of renewables. It is necessary to study the proactive dispatch strategy at a finer timescale to support the ultra-short-term power balance of distributed microgrids.

Based on the above challenges, taking into account the strong coupling characteristics of power supply and meteorological conditions, the flexible interconnection mode on the grid side, the diversified elasticity characteristics on the demand side, and the synergistic modes of the power system and other energy systems, this paper designs a data-driven technical framework of regulation and transaction, as shown in Fig. 11.

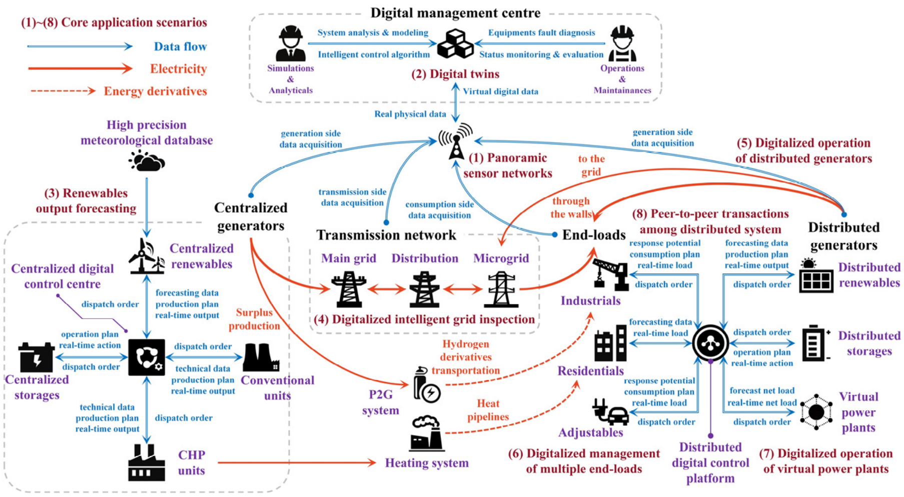

Fig. 11 Data-driven technical framework of regulation and transaction

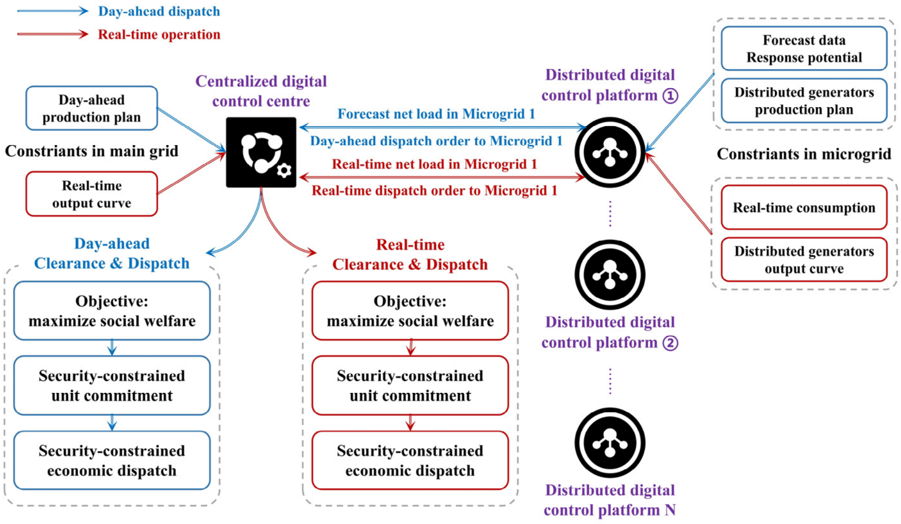

Fig. 12 The "cloud-edge collaboration" synergistic mechanism

3.1 Centralized generators

The centralized generators include centralized renewable power stations (mainly wind power and photovoltaic), conventional units (including thermal power units, hydroelectric generators, etc.), centralized energy storage systems, and CHP units. Based on meteorological forecasting data, unit technical parameters and other constraints, each generator submits data to the centralized digital centre, which, through the "cloud-edge collaboration" synergistic mechanism (see Fig. 12), takes the system net load curve and the dispatchable supply curve as constraints, adopts the unit commitment and economic dispatch algorithm to clear the market, then sends the corresponding dispatch instructions to each centralized power generator, which carries out the production plan, transmits the power to the main grid, and updates the real-time output curve through the digital regulation platform.

In addition, based on the synergy between the power system and other energy systems, centralized power supplies can also be used as an energy input for the production of hydrogen and its derivatives through the power-to-gas system, through electrolysis tanks and other technical means. Hydrogen fuel can be directly supplied as energy to hydrogen refuelling stations and other downstream industry, as well as be mixed with natural gas transportation into the natural gas pipeline for the demand side of the industrial load, but also can be further converted into ammonia for industrial and agricultural use, greatly broadening the conversion of electric energy and functional uses, significantly enhancing the system flexibility. At the same time, CHP units are capable of producing heat resources to supply residents in line with the synergistic regulation, which can further improve the efficiency of energy utilization. The synergy between the power system and other energy systems can provide additional adjustable load capacity, which can help to convert electricity into other forms of energy when the new energy unit generates abundant power, thus realizing the full consumption of power generated by the new energy unit, effectively improving the production efficiency of the whole energy industry, and lowering the total cost of carbon emission reduction.

3.2 Distributed microgrids

The wide access of distributed generators and the rapid popularization of diversified end-loads are considered comprehensively, in which the end-loads include industrial loads, residential loads and adjustable loads, and the distributed generators include distributed renewable units, distributed energy storage systems and virtual power plants. A regional distributed digital control platform should be deployed in each microgrid, which is used to obtain the data elements of each subject and provide them with control instructions. Distributed generators submit production plans to the control platform based on meteorological forecasting results and unit technical parameters, with the optimization objective of maximizing their own generation revenues. Industrial loads and adjustable loads submit their consumption plans to the control platform based on their own response potential and with the optimization of maximizing the net utility of their own power consumption; virtual power plants submit forecast net load to the control platform based on the integration of power generation resources and power consumption loads in the jurisdictional area. The distributed control platform takes the above data as the boundary conditions, adopts unit commitment and economic dispatch algorithm to clear the market, calculates the net load forecast data of the micro-network in the control period and submits it to the centralized control centre, which optimizes the whole system through the "cloud-side collaboration" mechanism (see Fig. 12). After the clearance, each distributed control platform sends dispatch commands to the market members within its jurisdiction, and obtains the real-time load curves of each terminal load and the real-time output curves of the distributed generators through the digital platform to realize the optimized operation among microgrids.

3.3 Digital management centre for electric equipments

The implementation of a panoramic grid intelligent sensor network and the establishment of a digital management centre for power equipment will aid in enhancing the digital productivity level of the power system. This will enable the entire new power system to be better observed, described, and controlled. On the one hand, it is necessary to deploy intelligent sensors in each link of the system, in order to realize the comprehensive perception and real-time monitoring of each electric power equipment. Particularly, as for the grids, it can realize the comprehensive analysis and assessment of the operating status, environmental conditions and fault defects of transmission lines, substation and distribution stations, etc., and provide data for the O&M department to carry out the corresponding obligations; as for the loads, it can collect data elements such as the regulation status of distributed power generation resources, electric vehicles, intelligent buildings and other new subjects in real time to support the efficient regulation of distributed microgrids. On the other hand, the simulation and analysis department can make use of the massive real-time data of each link to construct a digital twin model for multiple scenarios and devices, simulate and optimize the system operation under multiple scenarios, and at the same time, realize the endogenous evolution of the digital twin system, which significantly improves the observability and describability of the new power system. In addition, it is necessary to establish a communication network based on intelligent sensors to realize two-way communication between terminal devices and the management centre, which can not only regulate the physical equipment based on the synchronous interconnection characteristics of the digital twin model, but also realize management of the devices through the edge computing and other distributed architectures to significantly improve the controllability of the system.

4 Conclusion

Digital empowerment is an essential path to realize the transition of the new power system. It will significantly reshape the traditional configuration of electricity channel, from partial perception and one-way control to a high degree of perception and two-way interaction. The empowerment will manage to optimize the energy flow and business flow led by data flow, bringing about certain capability of strong perception, intelligent decision-making, and fast execution. Ultimately, a diversified integration of highly flexible power grid will be created to adapt to a high proportion of renewable resources and power electronic equipment to the system security and economic management.

Based on the inherent characteristics of the new power system, this paper takes the new transformation of its two major operation businesses, namely regulation and transaction, as the entry point, focusing on the system's significant demand for digital technology support in the core operation obligation, and then clarifies the mechanism of digital empowerment of the new power system. We further put forward the core application scenarios of the digitized new power system, and form the technical architecture of the regulation and transaction empowered by digitization, hoping to provide a theoretical reference for the transformation of the new power system operations.

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