Study on the Connotation and Framework of Regional Integrated Energy System

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Abstract. Under the background of energy interconnection, the traditional mode of energy supply, which is based on production to meet the demand, will be completely overturned. All participants in the energy interconnection are both "producers" and "consumers". Interconnection and sharing will become the core values in the new energy system. This paper mainly expounds the connotation and characteristics of regional integrated energy system, and at the same time constructs the overall framework including the inner "three-level structure" and the external "three-function system". Finally, it preliminarily proposes the technical framework of regional integrated energy system including a variety of key technologies.

1. Introduction

In the face of the development tide of the world energy interconnection, the traditional energy supply mode of adapting production to demand has been subverted gradually, and the energy interconnection has attracted more and more attention from all over the world. Therefore, the development of the energy interconnection is imperative.

Foreign countries have made a forward-looking study on the energy interconnection in the past. Jeremy Rifkin, a famous American scholar, took the lead in putting forward the concept and characteristics of energy interconnection, and expounded the main characteristics and development trend of energy interconnection in the future [1], which provided a good sample for the construction of energy interconnection in the future. In addition, some domestic scholars have also explored the framework and connotation of energy interconnection. Relevant scholars initially put forward the concept, architecture and frontier outlook of energy interconnection [2], and then further elaborated on its structure design and topology model and other related research work [3]. However, the research on energy interconnection at home and abroad is limited to the ideal framework, basic concepts, integration schemes and mechanisms of energy interconnection. There are few discussions on how to apply relevant technologies to build regional integrated energy system. Therefore, through the elaboration of the connotation and characteristics of regional integrated energy system, and through the construction of its
overall framework, this paper finally puts forward the technical framework of regional integrated energy system, which provides theoretical support for the future development and construction direction of regional integrated energy system in China.

2. The connotation and characteristics of regional integrated energy system

2.1. The connotation of regional integrated energy system
The energy interconnection is a smart energy network centered on electricity, based on a strong smart grid, supported by the ubiquitous Internet of things, deeply integrating advanced energy technology, modern information communication technology and control technology to achieve multi-energy complementarity, intelligent interaction, and ubiquitous interconnection. It is a new value creation platform and ecological system that is fully connected with the whole elements, production chain and value chain in the energy field, which is also the concrete realization form of industrial Internet in the energy field. The regional integrated energy system will take the province as the entity, break the interactive barriers of each link of the provincial energy system, realize the horizontal cold, hot, electricity and gas complementary, vertical source, network, load, storage space and time each other, and promote the high-quality development of regional energy.

2.2. Characteristics of regional integrated energy system
The regional integrated energy system is characterized by openness, interconnectivity, equality, publicity, efficiency, and intelligence [4].

(1) Openness. It is highly open both in technology and industry, which supports the indiscriminate access of distributed multiple systems and devices and the indiscriminate participation of various energy entities. It can form a highly open energy trading market and an innovation and entrepreneurship ecosystem

(2) Interconnectivity. It supports the two-way flow of energy and information, breaks down barriers in different energy industries, realizes the comprehensive utilization and coupling of multiple forms of energy such as electricity, heat, cold, gas, oil, transportation, etc., and provides a communication medium for the integration of the energy industry with other industries.

(3) Equality. By lowering the access threshold of the energy market, energy users, regardless of their size, can participate in the energy market and auxiliary service market fairly. The boundary between supply and demand is gradually blurring, and each participant is both producer and consumer.

(4) Publicity. It can attract more social capital and various market entities to participate in energy interconnection construction and value creation, drive the upstream and downstream development of the industry chain, and share development results with the whole society.

(5) Efficiency. It realizes the organic cooperation and coordination of energy resources production, transportation, storage, conversion and utilization through energy conversion technology, information flow and energy flow interaction technology, source network charge storage coordination control technology, etc., promoting the optimal energy efficiency of the energy system as a whole.

(6) Intelligence. It can deepen the integration of advanced technologies such as the Big Cloud and the wisdom chain, effectively improve the ability to control complex systems, cope with complex scenes, and improve the safety and economy of energy and power system operations.

3. The overall framework of regional integrated energy system
Based on the current research results of energy interconnection forward-looking theory, and taking into account China's provincial conditions, energy and network conditions, the internal "three-level structure" and the external "three-function system" concept of regional integrated energy system construction are proposed.
3.1. Three-level structure
The “three-level structure” is the framework form of the regional integrated energy system, the physical infrastructure layer that carries the energy infrastructure, and the information fusion layer of the intelligent Internet of Things Center, the data center station, the business center station and the artificial intelligence middle platform, which is also conduct application and practice layers for internal and external business[5]. Its main structure is as follows:

(1) Physical base layer: New energy infrastructure with information physical integration system as the core.

Energy-side infrastructure with grid as the core: It takes power network as the main framework, integrates gas, heat and other networks, provides interfaces for other energy networks, and integrates and transforms them. It covers the whole link including energy production, transmission, consumption, storage and transformation, and has flexible and extensible capacity to support plug and play and two-way interaction of distributed energy and multiple loads.

Information-side infrastructure with data sensing measurement, content coupling agent and communication networks as the core: It includes information collection and transmission systems based on various types of sensors, optical fibers and wireless communication networks. It mainly promotes horizontal and vertical coordination of energy data and deeply covers all aspects of energy production and consumption.

(2) Information fusion layer: The central control system with "one center and three middle platforms" as the core.

Management center of the association of things: It integrates the fields of power transmission and transformation, distribution network, user side and supply chain, etc. to meet the extensive requirements of material connection and depth perception, and realizes the construction of equipment management, edge calculation, safety monitoring, unified management of material connection and protocol compatibility, standard system and other aspects.

Data middle platform: It is demand-oriented, based on a unified data model, to achieve high-speed storage and professional processing of large data information, and gradually realize the data integration of power grid, industry, finance, internationalization and other sections. On this basis, the “Power Private Cloud” is established to realize the unified data source of the internal business, and at the same time, the external public cloud is established to realize the co-construction and sharing of public data by enterprises, customers and suppliers, and fully exploit the data value.
Business middle platform: It is internally oriented to the business, and deeply promotes management change, professional collaboration and service sharing, and builds a grid resource business center that is built and shared by various disciplines based on the data homology maintenance mechanism. It focuses on serving customers and builds a customer service center with digital and online levels to effectively form common service capabilities, improve customer service quality, and promote business performance.

Artificial intelligence middle platform: It can build open artificial intelligence algorithm libraries and calculation engines to provide unified artificial intelligence service.

![Information fusion framework diagram](image_url)

Fig. 2 Information fusion framework diagram

(3) Application practice layer: realize internal quality and efficiency improvement and external energy value-added services.

Internal applications: It can realize lean planning, intelligent inspection, flexible scheduling and cross-professional information communication of smart grid. It can also establish unified data model, strengthen enterprise-level master data management, promote business process online closed loop, improve business digitization and online level, enhance lean management ability, support market development and value creation, and improve business performance.

External services: It can effectively aggregate various resources, carry out energy planning and design, operation and maintenance, aggregation transactions, energy efficiency analysis and other services, realize smart energy operations, and realize business diversion through an online unified portal. It develops smart energy business models for energy producers, energy service providers, energy consumers and other entities, and realizes industrial empowerment by virtue of platform advantages. It is aimed at government, industry institutions and other entities to promote data sharing and decision support services. Finally, it will build an energy interconnection service ecosystem that is open, shared and win-win.
3.2. Three-function system

The three-function system is an energy supply system centered on resource optimization and configuration, an asset management system centered on safety benefits, and a modern service system centered on customers[6]. Its specific functional system is as follows:

(1) Energy supply system centered on resource optimization and configuration

The energy supply system focuses on the energy industry and runs through the entire processes of energy production, conversion, storage, transportation and consumption to achieve optimal allocation of energy resources and comprehensive improvement of comprehensive energy efficiency. In order to build an energy supply system, on the one hand, it is necessary to make full use of the spatial and temporal distribution characteristics and complementary coupling characteristics of various types of energy to achieve an overall balance of supply and demand of multiple types of energy, and to use a strong and interconnected smart grid as a carrier. It cooperates with gas and heating pipe networks to achieve multi-energy coordination and mutual assistance, and realizes a wide range of optimal allocation of energy resources. On the other hand, it is necessary to give full play to the pivotal role of power grid in energy gathering, transmission, conversion and utilization, promote the efficient conversion between electricity, cold and hot energy, realize the comprehensive conversion and utilization of various energy sources, reduce energy consumption in the process of energy production and consumption, and realize the significant improvement of comprehensive energy utilization efficiency, which provides a solid foundation for large-scale grid connection and consumption of clean energy, distributed energy, energy storage and interactive power facilities, leads the clean, low-carbon, safe and efficient energy system construction, and promotes the transformation and development of the energy industry.

(2) Asset management system centered on safety benefits

The asset management system aims at internal network operation and optimizes the internal efficiency of regional integrated energy system through efficient management and value mining of power grid assets and data assets. It can establish an asset management system to coordinate the investment, construction and operation and maintenance of power grid assets and data assets. For power grid assets, it focuses on solving the problem of “block management” of traditional asset management in planning, transportation inspection, materials, finance, etc., constructs a closed-loop management system of asset life cycle with “planning plan-procurement construction-operation maintenance-decommissioning disposal” to achieve comprehensive optimization of risk, efficiency and cost. For data assets, on the one hand, it collects data flows in the state, behavior, and business transactions in the production and operation process to form data assets. On the other hand, it can build the data asset management process of "asset creation - data processing - development and implementation - value-added application - maintenance and inspection - archiving and retrieval - update - deactivation and removal", and focus on the combination of digital technologies such as "The Great Things Transfer Wisdom" to dig into the value of digital products and realize the value-added service of data assets.
(3) Modern service system centered on customers

Modern service system is oriented to the whole society, customer-centered, with "drainage and empowerment" as a means to create and share social value. To build a modern customer-centered service system, the key is to build a "one-stop" intelligent energy platform for customer aggregation, business integration and data sharing. According to different customer needs, four service modes are constructed. The integrated energy service model provides one-stop energy service with customized energy supply as the core for energy consumers. The industrial enabling service mode provides a series of enabling services for small and medium-sized enterprises on access platform, such as transaction matching, intelligent procurement, supply chain optimization, etc. Drainage incubation service mode introduces the funds, technology and policy support needed for platform construction on the one hand, and excavates relevant value points to incubate on the other hand. The social service model provides decision support and value sharing services, and guides the whole society to create a win-win modern service ecosystem.

For energy consumers, it focuses on providing customized energy products and one-stop services with integrated energy business as the core, including household energy management, smart home services, electric vehicle services, distributed energy services, energy trading platform services, integrated energy efficiency services, e-commerce platforms and other businesses, forming a benign intelligence. Interaction.

For equipment suppliers, it is oriented to energy and power production, transmission, storage and other links. Through the comprehensive platform of energy services trading, it attracts all kinds of energy suppliers, such as electrical equipment, telecommunications services, materials suppliers to be stationed, provides them with a series of supply chains such as intelligent procurement, digital logistics, panoramic quality control, and establish a feedback mechanism for both suppliers and consumers on product use experience.

For service providers, it is based on open platform of commonality resource basis functions such as data analysis, agglomeration partners with complementary services functions, including technical service providers and consulting service providers in the upstream and downstream of the industrial chain, as well as cross-border supporting service providers such as financial insurance and advertising value-added, which exerts the effect of drainage aggregation and timely hatches emerging technologies through double-creative services.

For social organizations, it actively meets the needs of people's livelihood government affairs, gives full play to the power data resources and planning and design capabilities, provides data and research consultation for government decision-making, urban planning, scientific research institutions, actively serves economic and social development, and at the same time seeks government policy support and other social resources sharing in the process of building a modern service system.

4. Technical framework for regional integrated energy system

Aiming at the overall framework of the regional integrated energy system, which includes the internal “three-level structure” and the external “three-function system”, this paper preliminarily puts forward the technical framework of the regional integrated energy system, including 11 key technologies, such as intelligent technology of energy interconnection production and consumption, multi-energy flow energy exchange and routing technology.

(1) Intelligent technology of energy interconnection production and consumption: It studies the intelligent production of renewable energy, fossil energy, and multi-energy intelligent collaborative production technology. It studies intelligent energy consumption technologies such as intelligent energy terminal, intelligent monitoring and regulation. It also studies integrated energy and intelligent building technology. It combines distributed energy generation with natural gas network and building energy saving to achieve integrated and optimized operation of three major energy systems, namely, cold, heat and electricity.

(2) Multi-energy flow energy exchange and routing technology: It studies flexible, efficient and standardized energy interconnection network topology. It studies energy routers, energy switches,
energy network cards and other key equipment. It studies basic technologies such as new power electronic devices and superconducting materials suitable for energy interconnection. It studies the mechanism and method of multi-energy flow energy exchange and routing, and establishes a standardized energy switch and router system architecture and functional indicators. It studies the multi-energy coupling energy interconnection operation and control reliability technology to ensure the high reliability of energy interconnection operation. It can complete the mechanism analysis and function of multi-energy exchange and routing, and realize the practical application.

3) Energy storage application and management technology: It develops distributed energy storage devices that support plug and play, flexible trading and electric vehicle application technologies in various application scenarios of energy interconnection. It develops core equipment to support flexible transformation, efficient storage and intelligent collaboration of various energy forms, such as electricity, cold, heat, gas, hydrogen, storage and so on. It develops key technologies to support modular design, standardized access, hierarchical utilization and network management of energy storage equipment.

4) Energy informatization and information physics fusion technology: It studies the theoretical framework and methods of energy information digitization. It studies the unified modeling and security analysis technology of information-energy coupling. It studies the integration technology of information physical energy system, such as system structure optimization, network collaborative control of multi-information physical energy system. It studies open interface standard of information physical energy fusion technology. It also studies the use of energy information and network control to activate the fragmentation of flexible stock energy resources technology.

5) Energy interconnection information and communication technology [7]: It studies the new architecture of mass information acquisition technology for energy interconnection and the core technology of efficient transmission and processing. It studies all kinds of new sensors supporting large-scale distributed power supply, load metering, monitoring and other functions. It studies information physical system data, terminal customer information, physical network data and other energy interconnection massive information technology processing and fusion technology. It also studies energy interconnection information security technology.

6) Energy trading service platform technology: It studies market trading platform technology that meets all kinds of functions of energy interconnection. It studies the new market structure design technology of ecology of energy structure, integration of production and energy, and high efficiency of resource allocation. It develops an automatic transaction and real-time settlement technology system based on identity recognition. It studies financial services technology based on energy interconnection. It develops energy interconnection financial products and financing tools that serve the whole life cycle of energy production, transmission, storage and consumption. It also studies energy system security technology in the context of free energy trading.

7) Intelligent energy management and regulation platform technology: It studies smart energy precision management technology based on big energy data to support energy planning, reform and decision-making. It is based on the energy interconnection, covering all areas of energy production, circulation, consumption and international cooperation, and modern energy regulatory technologies that are compatible with the level of smart energy development.

8) Energy big data and its application technology: It studies various large data integration technologies such as big data for energy interconnection users, big data for equipment, big data for operation, big data for transaction, big data for finance and so on. It studies the key technologies of multi-source data integration, fusion and value mining. It studies the supporting technology of big energy data in guiding government decision-making, improving business level and service quality of enterprises, and innovating business model of energy industry. It completes the integration and value mining of large data, studies the technology of virtual power plant, and analyses the impact of large data on energy market and demand side response.

9) Energy virtualization technology: It studies virtual power plants, distributed energy forecasting, integrated optimization control of regional multi-energy systems and distributed optimization technology of complex systems. It studies energy virtualization technology to participate in energy
market, ancillary service market, carbon trading market and other supporting technologies of multi-energy system. It also carries out the pilot work of energy virtualization technology participating in market transactions in areas with high degree of automation of energy systems and rich distributed energy resources.

(10) Demand response resource interaction technology: It studies demand side response interaction technology based on intelligent energy use. It studies demand response modeling technology based on user behavior psychology and other interdisciplinary means. It studies the key technologies of demand response resource identification and quantification, demand response measurement, demand response participation in ancillary service settlement, etc. It also studies market support technologies for ancillary services such as demand response participation system peak shaving and frequency modulation.

(11) Intelligent asset management technology: It studies the intelligent state assessment and early warning technology based on the whole life cycle of assets. It studies asset condition maintenance technology centered on reliability and risk assessment. It studies the intelligent robot technology that supports cost-benefit analysis of transaction and efficient operation and maintenance of unmanned.

5. Conclusion
Based on the connotation and characteristics of the regional integrated energy system, this paper gives overall consideration to the provincial, energy and network conditions of China, and proposes the internal "three-level structure" and the external "three-function system" of the regional integrated energy system construction. On this basis, this paper puts forward the technical framework of regional integrated energy system, including 11 key technologies such as intelligent energy interconnection production and consumption technology, multi-energy flow energy exchange and routing technology, which provides theoretical support for the future development of regional integrated energy system in China.

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