Analysis of the Development Status and Prospect of Multi-energy Complementary Technology

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Abstract. Multi-energy complementary is an effective way to improve the overall efficiency of the energy system, improve the coordination of energy supply and demand, and promote the immediate consumption and efficient use of clean fossil energy and renewable energy. The implementation of the multi-energy complementary integration optimization project has prompted China to overcome a series of related technical problems in the energy field. This paper summarizes the current status of China's multi-energy complementary development, explores industrial policies such as technology, economics, and institutional mechanisms accumulated during the process of multi-energy complementary development, and analyzes the development prospects of multi-energy complementary, with a view to better promoting regional clean fossil energy utilization levels and renewable energy technology advances contributions.

1. Introduction
China's multi-energy complementary development is inseparable from the government's energy development planning layout and industrial policy support and guidance. In terms of development planning, in 2007, the "Eleventh Five-Year Plan for Energy Development" proposed a renewable energy industrialization project, which listed low-cost, large-scale development and utilization of renewable energy as one of the advanced and applicable technologies for key development. Renewable energy sources such as wind power generation, biomass power generation, biomass molding fuel, and solar energy utilization with large resource potential and basically mature technology are used to drive industrialization development with large-scale construction. For the first time, the "distributed energy supply system" was listed as one of the frontier technologies for key development, focusing on strengthening the research of terminal energy conversion, energy storage, integrated technology of heat and electricity cooling systems such as micro-small gas turbines and new thermal cycles. This paper studies the technology, economy and institutional mechanisms accumulated in the process of multi-energy complementarity, and analyzes the development prospects of multi-energy complementarity, with a view to better promoting the promotion and promotion of advanced technologies related to multi-energy complementarity in China, and contribute to clean fossil energy utilization level and renewable energy technology progress.
2. Multi-energy complementary development policy environment

2.1. Development plan
In December 2016, the National Development and Reform Commission and the National Energy Administration jointly issued the "Energy Production and Consumption Revolution Strategy (2016-2030)", proposing to build an "Internet +" smart energy. Strengthen the intelligent construction of the power system, effectively connect the oil and gas pipeline network, heating pipeline network and other energy networks, promote the interconnection of various types of energy flow networks and the coordinated transformation of multiple energy forms, and build "source-network-charge-storage" coordination Develop and integrate complementary energy internet.

2.2. Industrial policy
On July 4, 2016, the National Development and Reform Commission and the National Energy Administration issued the "Implementation Opinions on Promoting the Construction of Multi-energy Complementary Integration and Optimization Demonstration Projects", clearly proposing the construction of multi-energy complementary integration and optimization. The demonstration project is one of the important tasks of building an "Internet+" smart energy system, which is conducive to improving energy supply and demand coordination capabilities, promoting clean energy production and nearby consumption, reducing wind curtailment, light curtailment, water curtailment, and promoting renewable energy Consumption is an important starting point for improving the overall efficiency of the energy system, and has important practical significance and far-reaching strategic significance for building a clean, low-carbon, safe, and efficient modern energy system. It is pointed out that there are two main modes of the multi-energy complementary integration optimization demonstration project: the terminal integrated energy supply system and the wind, water, water and fire multi-energy complementary system.

3. Analysis of multi-energy complementary system integration technology

3.1. Multi-energy complementary system integration mode
Multi-energy complementary integration is mainly based on making full use of the characteristics of various forms of energy, to optimize the combination, to achieve the purpose of integration optimization. At present, the complementary integration modes of various energy forms can be roughly divided into the following three types.

3.1.1. Complementary integration mode between electric energy. The complementary integration mode between electrical energy is a complementary integration mode with electrical energy as the core. In this mode, various energy forms are used to generate electricity. Through the integrated control strategy on the electrical energy side, the stability of the output is ensured to achieve external energy The integrity of the output is controllable. Common examples include wind-solar storage combined power generation, wind-fire bundling power generation, and micro-grid mode.

3.1.2. Electro-thermal complementary integrated mode. The electro-thermal complementary integrated mode is a mode in which full thermal energy is complementary. In this mode, electrical energy of various renewable energy sources can be converted into heat, and complementary integration can be achieved through direct or indirect utilization of heat. Common examples include biomass and coal-fired power generation mode, combined solar-thermal and thermal power generation mode, and combined cooling and heating power supply mode.

3.1.3. Electro-chemical energy complementary integrated mode. The electro-chemical energy complementary integrated mode is a mode that uses chemical energy as a complementary medium. In this mode, it can make full use of renewable resources to be converted into the form of chemical energy,
and then into electrical energy or heat energy. Common examples such as hydrogen/gas/ethanol production from renewable energy sources, fuel cells, etc.

3.2. Operation control technology of multi-energy complementary system

3.2.1. Multi-energy complementary optimization control technology. The goal of joint operation of multi-energy complementary systems composed of wind energy, solar energy, hydropower units, etc. is mainly to eliminate or reduce the intermittency and volatility of wind power and photovoltaic power output power, and reduce this uncertainty to the grid system operational risk. Such a multi-energy complementary system should fully consider economic benefits and environmental benefits during operation. The multi-energy complementary system containing wind, light and water operates according to the expected input power set by the power grid, so as to achieve the purposes of peak clipping and active load control. Under normal circumstances, the predictability and controllability of wind power and photovoltaic power are not as good as hydropower. Need to investigate the difficulty of control, the amount of operations required to achieve control goals is more or less. It is also necessary to examine the control loss, the impact on each device when taking control measures, and the power quality impact, and the impact on power quality after control. Through the inspection of these indicators to determine the control target, through the correlation to determine the speed and intensity of control, and ultimately achieve the purpose of coordinated control.

3.2.2. Virtual power plant technology. The virtual power plant is an advanced information communication technology and dispatch control system to realize the aggregation, coordination and optimization of multiple types of energy sources such as wind, light, water, fire and storage, as a dispatch system for a special power plant to participate in the power market and grid operation. The emphasis of the virtual power plant is the overall control effect presented to the outside world. Renewable energy represented by wind power and solar energy has significant intermittent and strong random fluctuations. If a single form of multiple renewable energy generator sets is connected to a large power grid on a large scale, it will cause serious system stability problems. Severely restrict the large-scale development and utilization of renewable energy power. The mode of integrated optimization and complementary operation of renewable energy power and traditional energy provided by virtual power plants can provide stable power output characteristics for large power grids under intelligent collaborative regulation and decision support. The main technical core includes multi-energy flow coordination control technology, intelligent measurement technology and information communication technology.

3.2.3. Energy storage technology to suppress renewable energy power fluctuations. Energy storage is widely used in power grids. In renewable energy power generation systems represented by photovoltaics and wind power, a certain capacity of energy storage configuration is often required to ensure a high proportion of energy consumption. Energy storage plays an important role in all aspects of power generation, transmission, distribution and use. With its rechargeable and releasable operating characteristics, energy storage systems can take into account the characteristics of capacity and power requirements, as well as excellent environmental protection. They can fully utilize the advantages of renewable energy power generation, balance their random fluctuations, maintain system stability, and improve power quality. Equipped with a certain capacity of synchronous power generation unit or energy storage unit in the system to suppress load fluctuations, peak shaving and valley filling, complementary with wind power, photovoltaic power generation and other renewable energy power generation technologies to reduce the impact of renewable energy on natural factors. The resulting power fluctuations stabilize the power output of the system, enhance the schedulable performance of the renewable energy power generation system, realize peak clipping and valley filling, and planned power generation.
4. Prospects for the development of multi-energy complementary technology

4.1. In terms of technical

Due to the existence of the stage, balcony, side light rooms, plenty staggered floor plans, and more than. The focus of multi-energy complementarity lies in integration optimization, that is, how to combine energy resources in the process of energy integration, solve the operational control problems caused by multi-energy flow, and achieve complementary advantages and coordinated optimization. The innovation of the core technology is an important guarantee for safe, reliable and high-quality operation of multi-energy complementation. The application of multi-energy complementation faces the problem that the control object changes from single to diverse. The type of energy and the response law are different. A series of challenges were presented. In the process of multi-energy complementary construction, continuous technological innovation is required to ensure safe, reliable and high-quality operation.

Multi-energy complementary projects are quite different from traditional energy projects in terms of business model, technical standards, construction process, operation model and maintenance methods, etc., promote the formulation and revision of multi-energy complementary integration optimization technology related standards, and clarify the definition of multi-energy complementary systems Scope and technical requirements, and formulating corresponding standards will help regulate the construction of multi-energy complementary projects. These standards have greatly promoted the orderly and regulated energy construction, and regulated the development direction of multi-energy complementary related technologies. With the development of technology, these standards are still in the process of continuous revision and reformulation. The technical standard system that advances with the times will help the development of multi-functional complementary technologies.

4.2. In terms of economic

The acquisition of multi-energy complementary economy depends on the rational use of resource endowments. According to the distribution area of the first batch of multi-energy complementary integration optimization demonstration project projects in 2017, the wind, water, fire and energy storage multi-energy complementary system is mainly concentrated in Zhangjiakou, Baotou, Sichuan, Shaanxi, Qinghai and other places where renewable energy is relatively concentrated. Natural gas, wind energy and solar energy are relatively abundant, and they are also the hardest hit areas of renewable energy consumption. Terminal integrated energy supply systems are widely distributed in technology and business districts with obvious terminal energy consumption characteristics, such as Beijing Lize, Hefei Airport Economic Demonstration Zone, Shenzhen Low-Carbon City, Jiangsu Gaoyou Chengnan New Economic Zone, and Wuhan Future Technology City. The construction of multi-energy complementarity in these areas is based on the local natural resources, load energy use and other actual conditions for targeted project construction, so it is relatively easy to achieve success.

A good business model is the key to solving the problems of multi-energy complementary investment and financing and operation. In the process of building multi-energy complementary systems in China, we gradually explored and formed the BOT model, BOO model, EMC energy contract model, PPP model, BT model, etc., which solved the funding needs and profitability of the multi-energy complementary system construction to a certain extent. Energy market price formation and trading mechanisms are important conditions for achieving multi-energy complementary profitability. In terms of the energy price formation mechanism, the market-based pricing model refers to the combination of government pricing and market competitive pricing to obtain social welfare and economic benefits for the purpose of setting electricity prices. China is currently carrying out power reforms, introducing competition, breaking state-owned monopolies, and giving users more options. Regarding the trading mechanism, China is already exploring the establishment of power trading centers in various regions, conducting cross-regional and cross-provincial trading rules, and ensuring that energy trading centers conduct transactions and provide services in accordance with the rules.
4.3. *In terms of institutional mechanisms*

Energy top-level design is conducive to guiding multi-energy complementation and correct development direction. The top-level design has an important guiding role in the process of multi-energy complementary development and can establish the development direction of the energy system. Strengthen the overall coordination and integration optimization of the energy system, promote the coordinated and coordinated development of various energy sources, and greatly improve the efficiency of the system, "vigorously promote the integrated energy supply of heat, electricity, cooling, and gas, and accelerate the construction of "Internet +" smart energy," The promulgation of these programmatic official documents has greatly pointed out the direction of energy construction in the current and future periods. The inclusion of multi-energy complementarity into one of the means for the development and improvement of the energy system has guided China's multi-energy complementarity development to a certain extent.

Industry guidance and support policies can effectively promote the rapid development of multi-energy complementarity. To a certain extent, multi-energy complementarity can also be regarded as an energy development policy. Therefore, industrial policy is one of the driving forces for the rapid development of multi-energy complementarity, mainly including government guiding or supporting policies, such as research and Demonstration projects, financing policies, subsidy policies, tax policies, etc. The reform of the energy system can break down the barriers that restrict the complementary development of multi-energy. Promote electricity and gas reforms, break the barriers of institutional mechanisms, restore the commodity attributes of energy, carry out reforms in market cultivation, full competition, entry and exit, and coordinate and coordinate energy, supply, electricity (gas, heat) networks Interests, change the existing models of separate planning, separate design, and independent operation of various energy supply systems such as power supply, gas supply, cooling, and heating, promote the interconnection of energy infrastructure, and strive to create good energy development and construction policies Environment, management mechanism, thereby promoting the development of multi-energy complementarity.

5. Conclusions

Promote the combination of production, teaching and research, strengthen system integration, optimize operation and other related technology research and development, and promote technological progress and equipment manufacturing capacity upgrades. To further promote the technical output cooperation of China's energy multi-energy complementary projects, government departments and enterprises should build on China's successful project experience to establish an excellent demonstration area of multi-energy complementary projects in China, and give priority to the approval and arrangement of projects with high levels of autonomy. Actively promote the construction of terminal integrated integrated energy supply demonstration projects, energy base wind, water, fire and energy storage multi-energy complementary demonstration projects, combine industrial demonstration with pilot reforms such as management systems, market construction, and price mechanisms, and explore to promote multi-energy complementary integration Optimize the effective model for large-scale development of demonstration projects, and better improve the use of clean fossil energy and technological progress in renewable energy.

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