Concept Development and Relationship Discrimination of New Power Network

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Abstract. Building a new power system is an important foundational transition towards a clean and low-carbon energy future that will lead to the realization of "Emission Peak and Carbon Neutrality". As the progress of building a new power system in China accelerates, it is of theoretical and practical significance to study the concept of a new power system and to clarify its relationship with other energy system concepts. Firstly, this paper analyzes the trends and challenges of energy and power development under the goal of "Emission Peak and Carbon Neutrality"; secondly analyzes the concept of a new power system, and clarifies what breakthroughs will be made in building a new power system in new future situations, and finally, identifies the differences and connections concerning the concepts of a new power network and the energy Internet and distributed smart grids, etc.

Keywords: "Emission Peak and Carbon Neutrality" · new power network · concept connotation · relationship discrimination

1 Introduction

On March 15, 2021, President Xi Jinping first proposed the concept of building a new power network at the Ninth Session of the Central Finance and Economic Commission. On October 26, 2021, the State Council issued the Action Plan for Carbon Dioxide Peaking Before 2030, further specifying the need to accelerate the construction of a new power network, that is a new power network with a gradually increasing proportion of new energy, which promotes optimal allocation of clean power resources on a large scale [1]. In March 2022, the National Development and Reform Commission issued the 14th Five-Year Plan for a Modern Energy System, which proposed accelerating the energy transition to green and low-carbon and promoted the construction of a new power network [2].

Building a new power network is a major developmental undertaking for the orientation of China's energy and power, profound changes will need to take place to allow the main power sources to be switched, adjustments made to the operating mechanism, the change in energy use modes, the reshaping of the market system, the existing power

S. Kadry et al. (Eds.): BDEIM 2022, AEBMR 233, pp. 624–634, 2023.
https://doi.org/10.2991/978-94-6463-124-1_72

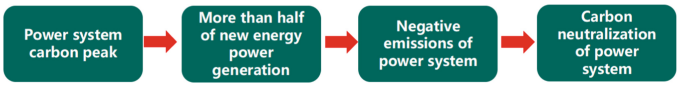

Fig. 1. Carbon neutralization trend of power system

structure, the development mode, industrial form, institutional mechanisms, science, and technology, etc. This paper studies the key theoretical issues in the development of a new power network from three aspects, including the development trends and challenges of energy and power under this new situation, the concepts concerning a new power network, and concept discrimination between a new power network and other energy systems, to lay the theoretical foundation for the practical implementation of a new power network.

2 Energy and Power Development Trends and Challenges Under "Emission Peak and Carbon Neutrality"

2.1 Energy and Power Development Trends Under "Emission Peak and Carbon Neutrality"

At the general debate of the 75th Session of the United Nations General Assembly on September 22, 2020, President Xi Jinping announced that China would scale up its Nationally Determined Contributions (NDCs) by adopting more vigorous policies and measures, striving to peak CO2 emissions before 2030, and achieve carbon neutrality before 2060 (Fig. 1).

The "Emission Peak and Carbon Neutrality" goals have put forward higher demands for the transformation of low carbon energy, and the path of energy development under this new situation needs to be clarified. For the future energy trend, the energy supply side shows the trend of zero carbonization of electricity and fuel; the energy demand side shows the trend of high efficiency, re-electrification, and intelligence. This is mainly reflected by the following:

First, in the form of energy production. Energy production will shift from a centralized to a decentralized mode of production, with the core being decentralization, from a top-down tree structure of the existing power system to a flattening structure, and reciprocal interconnection between energy autonomous units.

Second, in the form of production and consumption. There will be a shift from producers and consumers being independent to demand-side users playing the dual role of consumers and producers through distributed energy, with each building turning into an independent energy producer and consumer.

Third, energy use in the future. It will transition from high-carbon to low-carbon to zero-carbon, to achieve the zero carbonization of electricity and fuel, and achieve the shift from supplementary energy to mainstream renewable energy.

2.2 Challenges Under "Emission Peak and Carbon Neutrality"

First, China has a large carbon emission base and will continue to grow for some time in the future. China is a major energy-producing and consuming country, thus producing

about 30% of the world's CO2 emissions from energy activities. Presently, China is still in the development stage of industrialization and urbanization, and the manufacturing industry is still located in the middle- and low-end of the value spectrum in the international industrial chain. With the development of economic and social development, the construction of new industrialization and new urbanization is accelerated, the energy demand will increase in the future, and related carbon emissions will continue to grow. By comparison, the total energy consumption of the United States, the United Kingdom, Germany, and other developed countries have basically stabilized or even started to decline, and CO2 emissions have peaked and steadily declined. In order to achieve the goal of carbon neutrality, our country will need to make greater efforts.

Second, China's energy consumption is still dominated by fossil energy, thus forcing us to face the arduous task of optimizing the energy structure. Currently, China's fossil energy consumption accounts for more than 80% of primary energy consumption, and carbon dioxide emissions per unit of energy are about 30% higher than the world's average. China's coal consumption still accounts for nearly 58% of primary energy consumption, accounting for more than half of the global coal consumption, per capita coal consumption is more than 10 times the world's average. From 2000–2019, China's total coal consumption increased by nearly 180%, accounting for about 90% of the global increase over the same period. While trying to actively promote the "de-coalification" trend promoted by the major developed countries, China who is the world's largest coal producing and consuming country is faced with tremendous pressure to further strengthen coal reduction policies and to replace some coal use with alternative energy sources, while also adjusting and optimizing the energy structure.

Third, it will be less than 30 years from when carbon emissions peak to the realization of carbon neutrality. Thus, the speed and strength of carbon emissions reduction create even higher demands. From the trajectory of carbon emissions by country, most developed countries in Europe peaked in the 1970s and 1980s, and the United States peaked at the beginning of this century. From the year in which the carbon neutrality goal is proposed by countries/regions, Finland, Austria, and Sweden announced achieving carbon neutrality between 2035–2045, and the EU, UK, Japan, and Korea announced achieving carbon neutrality by 2050. China must achieve carbon peaking by 2030 and then carbon neutrality by 2060, which is less than 30 years compared to the 50–70 year transition period in developed countries, which means that the speed of carbon emission decline and emission reduction intensity in China is much greater than that in other developed countries.

Fourth, advanced emission reduction technologies to achieve carbon neutrality goals have not yet been applied on a large scale. The wind and light as the representatives of the new energy generation technology are developing rapidly, and the cost is falling quickly, but its intermittent and volatile characteristics bring great challenges to the safe and stable operation of the power grid. China's energy storage industry is still in the initial stage of development, in addition to pumped storage technology, other energy storage technology is still mainly at the demonstration stage. Carbon Capture and Storage (CCS) technology [3] are an important means to solve the problem of high carbon emissions from coal power, but it is currently facing problems such as high cost, lack of viable business models, and the risk of sudden and slow leaching during transportation and

storage. The controlled nuclear fusion energy source is the ideal clean energy source of the future, but there are significant technical barriers.

Fifth, forest enhancement faces natural conditions [4], policy mechanisms, scientific and technological support, and other restrictions and obstacles. China's forest coverage rate is about 23%, lower than the 30.7% global average especially since the per capita forest area is less than 1/3 of the world's per capita, and the per capita forest growing stock is only 1/6 of the world's per capita, and the total forest resources are relatively insufficient, of low quality, and unevenly distributed. With the continuous development of China's economy and continuous urban expansion, land use conflicts are further intensified and the pressure to hold the existing forestry baseline and grassland resources is increasing. In addition, the effective incentive mechanisms and policy systems to promote sustainable forest management are still imperfect, the scientific and technological support for forestry and grassland is insufficient, and research on key technologies such as reforestation at difficult sites and the transformation of inefficient forests is lagging.

3 Concept Development of a New Power Network

The concept of a new power network originated from the background of China's "Emission Peak and Carbon Neutrality" goals, and the industry has different perceptions. Since March 15, 2021, when the concept of building a new power network was first proposed at the Ninth Session of the Central Finance and Economic Commission, many industry organizations, experts, and scholars have published their understandings of a new power network (see Table 1 for details). In 2021, the State Grid Corporation issued an action plan for the new power network (2021–2030), proposing that the new power network carries the historical mission of energy transformation, and is an important part of the clean, low-carbon, safe, and efficient energy network, with new energy as the main energy, ensuring energy and power security as the basic premise, meeting the power demands of the economic and social development as the primary goal, a strong smart grid as the hub platform, the interaction of source-grid-load-storage and multi-energy complements as support, and a power system with basic clean, low-carbon, safe, controllable, flexible, efficient, intelligent, friendly, open and interactive features.

The conceptual development of a new power network can be broadly summarized in three aspects by integrating the views of various parties: first, to reshape the physical form of the power network. By accessing a high proportion of new energy at the source end, the coexistence of a variety of grid forms at the network end, continuous optimization of the load-side power structure, and energy storage throughout all aspects of the power network, a new power network will be built by collaborating "source-grid-load-storage". Second, innovate the technical equipment of the power system. The new energy grid connection, digitalization, CCUS, and other technological innovations, lead the technical changes of the whole power system link including generation, transmission, and distribution, and effectively supports the conversion of various types of energy to electric energy and realizes load-friendly interactions under the premise of ensuring power supply security. Third, to innovate the institutional mechanism of the power system. With the integration and development of technologies, data, talents, and other elements, the construction of a national unified energy and electricity market will be

promoted, giving birth to a new type of industry and value spectrum of power networks that are green, low-carbon, intelligent, friendly, economic, and efficient.

As the new power network enters the construction phase the conceptual outline of a green, low-carbon, safe, reliable, source-grid-load-storage synergy, multi-energy complement, and digitalization as the main base has gradually become clear and reached a consensus. Greenness and low carbon are the directions, safety and reliability are the keys, and the source-grid-load-storage synergy, multi-energy complement, and digitalization are the means. Through the integration and innovation of energy technology and information technology, the new power network realizes extensive access to a high proportion of source end new energy, safe and efficient flexible allocation of resources at the network end, and satisfaction of diversified load demands at the load end, promoting green and low-carbon transformation in the energy sector and helps to achieve the "Emission Peak and Carbon Neutrality" goal.

4 New Power Network and Energy Internet Concept Discrimination

4.1 Starting with the Energy Itself

Broadly speaking, the energy Internet [5] is based on the improvement of the internal information and intelligence of each energy system, such as coal, oil, gas, electricity, and heat, to realize the connection of the digital layers between systems through advanced information, communication, and control technologies, and promote the overall coordinated operation and intelligent control of the energy system. Considering the entire industry, the energy Internet is a smart energy system with five characteristics: "cleanliness and low-carbon, safety and reliability, ubiquitous interconnection, efficient interaction, intelligence, and openness".

The new power network takes a strong smart grid as a resource allocation framework, with photovoltaic wind power as the main structure, coal power, and other energy sources as auxiliary structures, energy storage as a key element, source-grid-load-storage coordination, and multi-energy complementary structures as an important means, and deeply integrates the advanced information and communication technology, control technology, and low-carbon energy technology to achieve a green, intelligent, safe, and efficient power network with wide access to new energy on the source-side with a high proportion, efficient, safe, and flexible allocation of the resources on the grid-side, fully meeting multiple load demands on the load side. The strong smart grid is the foundation, and the realization of "carbon peak, carbon neutrality" is the end goal.

In a broad sense, the energy Internet will be the basic form of an energy system in the future, encompassing all forms of energy and describing the higher-order forms of energy development. As energy forms continue to develop, being load bearing and producing usable green low-carbon energy, the new power network is an important part and basic framework for the energy Internet.

In a narrower sense, the electricity-centered energy Internet, an advanced stage of the traditional power grid, is highly consistent with the new power system in terms of technologies, forms, and functions. Technologically, it emphasizes the integration and development of information and communication, energy and power, and advanced control technologies. In terms of its form, the grid framework is strong and guarantees

Table 1. Typical Cognition of New Power Networks Held by Industrial Organizations, Experts, and Scholars

Institutions/Scholars	Typical Cognition of the New Power Network
Wang Zhixuan, Former Full-time Vice Chairman of the China Electricity Council	The purpose of building a new power network is to achieve zero carbon (near-zero carbon emission) emissions from the power energy production and consumption system. The "main body" of new energy should be quantity, function, and responsibility. The main constraint of the new power network is energy system security. Implementation path: Ensure electric power security; strongly support the development of new energy; continue to improve the construction of a smart grid and pay more attention to the construction of a smart distribution network; clarify the positioning of coal power and strictly limit the construction of coal power; start the nuclear power construction while also ensuring safety, and start the construction of large hydropower facilities while maintaining ecology; promote the commercialization of energy storage.
Guo Jianbo, Academician of the Chinese Academy of Engineering	For today's power industry, photovoltaic power generation and wind power are the two types of power generation with the most mature technology and economy, the fastest development, and the largest scale effect in the world, and are the main sources of new energy that can be expected to be incrementally added; the main position of new energy power generation and the main responsibility of new energy units to support system operations are two important signs of the completion of the new power network. In the future, the country's centralized and distributed new energy generation units will reach tens of millions, with billions of signals. The new power network is a complex giant system with multiple spatial and temporal scales, multiple layers, and multiple system mergers.
CICC	The changes in the new power network mainly stem from structural changes on the generation side and the consumption side. On the power generation side: the random, volatile, and intermittent nature of new energy sources brings multiple system challenges. On the power consumption side: the structure of electricity consumption continues to be optimized, with an increase in load fluctuation and two-way interaction.
Shu Yinbiao, Academician of the Chinese Academy of Engineering	The new power network desires to utilize new energy as the main supply body to meet the growing demand for clean electricity, with a high degree of security, openness, and adaptability.

(*continued*)

Table 1. (*continued*)

Institutions/Scholars	Typical Cognition of the New Power Network
Li Peng State Power Investment Corporation (SPIC)	The new power network is the bridge between the supply and demand of clean energy. The essence of building a new power network is to highly-efficiently meet the operational needs of the new energy grid and to achieve efficient interaction among source-grid-load-storage by opening all energy supply and demand links. The new power network is an effective way to unlock the green value of electrical energy. The new power network facilitates the optimal allocation and dispatch of clean energy, guides the green transformation of the energy production and consumption industry chain through green power energy intermediaries, and realizes the smooth transmission of the green value of electric energy to end users.
Li Licheng, Academician of the Chinese Academy of Engineering	The source-grid-load-storage of the new power network integrates and transforms, the "energy and information" interwind and interact with each other, and the global data points are the link and basis to study the power network. Under the new power network, the energy and electricity tend to be integrated and pan-electrified, with the grid pattern of "large power grid + active distribution network + micro-grid". Transparency is the main feature of the new power network, which is a new network system built by integrating modern sensing technology, information technology, digital technology, and intelligent technology into the power grid, with a new form of "electromagnetic + digital state", a new network of "power grid + Internet" and a new capability of "power + computing capacity".
Tsinghua University Gao Feng	The new power system is the core framework for the energy Internet. The future power network is like the Internet system, with the platform to close the distance between supply and demand, to achieve supply and demand synergy, and wide public participation to form a new type of power ecology; with the data center, 5G network and other new infrastructures as support, through "technology + mechanisms" to innovate the power ecology so that the digital transformation and energy transformation go hand in hand.

the friendly interconnection and mutual benefit of various elements such as new energy. Functionally, it emphasizes resource allocation abilities and service support to ensure the rapid development of new energy.

Overall, the electricity-centered energy Internet and the new power network are unified and coordinated, being two sides of the same coin. The technology, form, and function are highly consistent, all of which are designed to implement the new energy security strategy of "Four Revolutions and One Cooperation", with important measures to achieve the "carbon peak, carbon neutrality" goals.

4.2 From the System's Architecture

The new power network is a comprehensive upgrade of a strong smart grid in terms of greenness, security, and intelligence. The strong smart grid is a new modern grid with ultra-high voltage. With ultra-high voltage grids as the backbone, the core processes are coordinated development of the grid at all levels, with information technology, automation, interactive features, and intelligent response capability, self-healing system capability, which are key and important foundations for building a new power network. Green upgrade refers to the status of the main body of new energy installed and the main body of electric quantity to further meet the urgent need for large-scale development with highly proportional access to new energy. Building a new power network doesn't just meet the large-scale and intensive development of centralized new energy and optimally wide ranged allocation, but also facilitates access to the distributed new energy and nearby consumption, but also effectively plays the role of grid energy resource allocation as a hub platform, supporting and serving as a clean process in the energy supply chain. Security upgrade refers to more accurate grid optimization, scheduling and operation modes, and control strategies, to ensure safe and stable system operation and reliable power supply of high quality. The construction of a new power network will fully utilize advanced transmission technologies, power electronics, low-carbon energy technologies, energy storage technologies, control technologies, and other advanced technical means to further improve system regulation capabilities and risk assessment capabilities to achieve a higher level of power security. Intelligent upgrade refers to the comprehensive improvement of information collection, transmission, processing, application, and other functions that promote the digital transformation of the power grid. Building a new power network will promote the integration of traditional grid infrastructure and new digital infrastructure, promote smart grid dispatching and operations, and the intelligence of operation management, thus realizing smart functions with digital transformation as the main drive.

Energy Internet is the expansion and extension of the new power network in business and industry. The new power network emphasizes the dominant status of the installed new energy and electric quantity, and the construction focuses on the innovation of power grid development and enhancing the regulation capacity of the system, which is a "green, safe, and intelligent" upgrade of the power grid and informational support system. Energy Internet is the organic connection of "three systems" of energy grid frameworks, information support, and value creation, of which energy grid system is the material basis of energy Internet and carries energy flow. The information support system is the nerve center of the energy Internet and handles the flow of information. The value creation system is the value realization carrier of energy Internet and carries business flow. The expansion and extension of the Energy Internet in business and industry refer to the continuous expansion of the applicational fields of electricity through industrial changes, deepening traditional values, and expanding emerging values, providing increasing diversity, personalized and low-carbon electricity services, and continuously innovating new industries, new business models, and new modes in the electricity industry as a result of economic development, social progress, and energy transformation.

4.3 From the Relationship Between the Two in Terms of Goals and Means

The construction of a new power network specifies the core objectives of "carbon peak and carbon neutrality" for the energy and power industry. The carbon emissions of the energy industry ranked at the top in terms of the total carbon emissions, and those of the power industry accounted for the highest proportion in the energy industry. Thus the key to achieving "carbon peak and carbon neutrality" is vigorously developing wind energy, solar energy, and other new energy. The construction of a new power network is an accurate grasp of the general trend of clean and low-carbon energy transition, is scientific positioning of the main position of new energy in the future energy system, and is a higher demand for the power system to play a key role in the service of "carbon peak, carbon neutrality", which greatly enhances the confidence and determination of the energy and power industry to accelerate the transformation and upgrading.

Promoting the transformation and upgrading of the power grid to the energy Internet is the right thing to do to build a new power network. Compared with conventional power sources, the generation of new energy is small in unit installed capacity, large in number, locationally scattered, and has significant intermittent, volatile, and random characteristics. With the large-scale development of new energy, a high proportion of grid connections, and a large number of applications of power electronics, the technical basis of the power system, control basis, and operation mechanism will undergo profound changes, and the power balance, security, and stability control will face unprecedented challenges, relying solely on a strong backbone network construction, technological progress and digital upgrading can not achieve a higher level of safe and stable operation and reliable power supply. The core of the energy Internet is to promote a multi-energy complement and source-grid-load-storage interaction, which contribute to extensive interconnection and efficient energy among various structures and the main framework. Therefore, this paper takes the strong smart grid as the basic platform to promote the upgrade of the grid to the energy Internet, which will effectively cope with the threat caused by a "double high" (high proportion of renewable energy, a high proportion of electronic power equipment) phenomenon of the power system after the large-scale grid connection and development of new energy, will become an important means to promote the rapid and healthy development of new energy, support the construction of a clean, low-carbon, safe, and efficient energy system and achieve the goal of "carbon peak, carbon neutrality".

In summary, the energy Internet is a higher-order form of the energy system, whose functional form and development direction are being extended and expanded with the times. Tracing the origin, the new power system is an important part of the energy Internet in a broad sense, and the electricity-centered energy Internet has a high degree of technological consistency, form, and function. To keep a foothold in the present, building a new power network is a comprehensive upgrade of the strong smart grid in terms of greenness, security, and intelligence. Building the energy Internet is an extension of the new power network in terms of business and industry. Looking forward to the future, building a new power network is the core goal of the transformation and development of the power grid with the end goal of "carbon peak and carbon neutrality", and promoting the transformation and upgrade of the grid to the energy Internet is the right thing to do to build a new power system (Fig. 2).

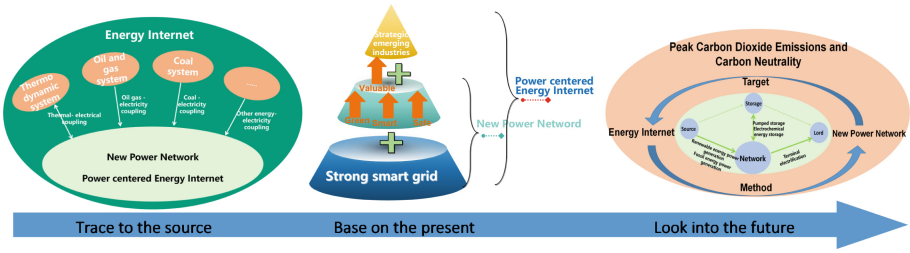

Fig. 2. Relationship between Energy Internet and new power system

5 Conclusions

Building a new power system is a strategic choice to accelerate the construction of ecological civilization, an important measure to ensure national energy security, a powerful force to build a new development pattern, and an important engine to promote the transformation and upgrading of the energy industry chain. The construction of a new power network will promote reform in the power market and technological innovation to make new breakthroughs. This paper examines the conceptual development and relational discrimination of a new power network and draws the following conclusions:

(1) Driven by the goals of "Emission Peak and Carbon Neutrality", the energy supply side shows the trend of zero carbonization of electricity and fuel. The energy demand side shows the trend of high efficiency, re-electrification, and intelligence; and faces a series of challenges such as large carbon emissions base, time constraints on carbon neutrality, difficult tasks of an energy structure optimization, urgent need for large-scale application of emission reduction technology, and many restrictions on deforestation, etc.

(2) With the start of the construction of the new power network, the conceptual outline of green, low-carbon, safe, and reliable, source-grid-load-storage synergy, multi-energy complement, and digitalization as the main framework has gradually become clear and reached a consensus: first, to reshape the physical form of the power network; second, innovate the technical equipment of the power system; third, to innovate the institutional mechanism of the power system.

(3) The electricity-centered energy Internet is an advanced stage of the traditional power grid, highly consistent with the new power system in terms of technology, form, and function. The new power network is a comprehensive upgrade of the strong smart grid in terms of greenness, security, and intelligence, and the energy Internet is an expansion and extension of the new power network in terms of business and industry.

Acknowledgment. Project supported by the management consulting project of State Grid Corporation of China "Research on the functional form and development path of provincial new power system" (SGJSJY00GHWT2200060).

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