Domestic and Foreign Energy Internet Construction Experience and Enlightenment

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Abstract. In this paper, firstly the overall energy structure and energy power development route of major developed countries are analyzed, and practice situations of energy internet engineering of different countries are analyzed by taking the United States, Germany and Japan as an example. Secondly, the overview, technical scheme and comprehensive benefits of typical domestic energy internet projects are analyzed. Finally, experience is summarized and suggestions are put forward for China's regional energy internet construction in terms of key technologies, operation model and pilot construction.

1. Introduction
American scholar Jeremy Rifkin put forward the concept of energy internet for the first time in the book The Third Industrial Revolution and depicted such a future scene: clean renewable energy can be stored and shared like information in the Internet, each building and family can access this energy internet and serve as the consumer as well as producer of energy and can sell surplus energy on the basis of self-sufficiency [1].

Revolution of energy technologies associates with progress and development of other industries. It will have proud influences on the social production mode and the people's way of using electricity. Therefore, different countries have input lots of capitals and labor force to carry out in-depth research of the energy internet. American government has put forward the revitalization plan of the manufacturing industry based on the Internet technology and intelligent manufacturing [2]; Germany and EU have put forward the Industry 4.0 plan [3] centering on the Internet and Intelligent manufacturing. Prime Minister Li Keqiang put forward the "Internet+" action plan in the 2015 Report on the Work of the Government. In a manner of speaking, energy internet technology means the overall improvement and development of the intelligent grid system which is under rapid development, which can realize more scientific and reasonable energy production, transmission and consumption in a variety of forms. The energy industry is a pillar industry of social production and development and has significant influences on development of other industries. Therefore, development of the energy internet technology is deemed by many researchers and experts as well as scholars as the core technology of triggering the fourth industrial revolution. Realization of the energy internet needs the support of technical innovation and the government mechanism and should arouse collaboration and high attention of each government, region and scholar of each country.

In view of the above reasons, comprehensive and in-depth research regarding domestic and foreign development conditions of the energy internet is carried out, and experience is summarized and suggestions are put forward for China's regional energy internet construction in terms of key technologies, operation model, pilot construction and enterprise transformation.
2. Foreign energy internet engineering practice
Take the United States, Germany and Japan for example, this chapter deals with energy internet engineering practice of these countries.

2.1. The United States
2.1.1. Energy policies of the United States
To implement new policies about new energy, the United States provides great supports for power generation with new energy in aspects of laws, policies as well as technologies and capitals. Initiated by National Academy of Sciences and National Academy of Engineering of the United States, the new energy research group of the United States has carried out all-round consideration and analysis of renewable resources and prepared objectives of three stages, roughly including:
- From now to 2020, preliminary deployment of new energy is implemented based on development of policies and technologies to form a complete set of reasonable industry procedure from manufacturing, production to power transmission and supply.
- From 2020 to 2035, the industry scale will be further expanded depending on improving core technologies and 20% of the total power supply will be realized in 2035.
- After 2035, renewable energy power generation technology will step onto a new stage in quality, the proportion of power generation with renewable resources will be higher and the country will try to realize popularization of power generation with renewable resources.

The new energy power industry policies of the United States are comprehensively considered based on its energy consumption status, energy safety guarantee and global competition strategies. The development and changes of its energy policies will affect development of its new energy industry and will bring new opportunities for energy cooperation between countries.

2.1.2. Energy internet practice in United States
OPower Company is an American enterprise which provides household energy management services for public utility companies. At present, the most eye-catching thing of OPower is that it can provide energy consumption comparison reports for users and their neighbours and provide tips for saving energy. And the company has obtained five million new orders from residential users with the help of 11 public utility companies, and the company has served 15 million homes with the help of 75 public utility companies.

OPower Energy Management Company carries out in-depth analysis and explosion of energy data of public utility companies and data of other types of third-party data so as to provide users with a complete set of energy saving suggestions suitable for their life style. Up to October 2015, it has helped users save 8.21 billion kW electricity accumulatively, equivalent to USD 1.03 billion of electricity fee, and has reduced 12.11 billion pounds of CO₂. As the scale of users increases gradually, increase of these data is accelerating. The practice of Opower is a typical case of big data application.

2.2. Germany
2.2.1. Energy policies of Germany
Germany is carry out the clean energy revolution, which aims at radically changing its traditional energy consumption structure. Presently, Germany's energy policy orientation is very clear, mainly including the following three aspects:
• Significantly reduce emission of greenhouse gases by 2050, reducing to 80%-95% of that in 1990.
• Improve the utilization proportion of renewable energy and accelerate its denuclearization progress.
• Reduce energy consumption and improve energy efficiency.

To realize the objective of 80%, combination and advancement with other measures is needed horizontally, and effects of each measure with respect to combined heat and power generation, PV and flexibility of the power system on the emission quantity of greenhouse gases in each field, such as power supply, heat supply and traffic, should be considered longitudinally.

2.2.2. Energy internet practice in Germany

To realize energy transformation, BMWI has launched the "E-Energy - future energy system based on ICT" promotion plan on the basis of intelligent grid and put forward the objective of forging new energy network. The E-Energy Plan aims at promoting regions and relevant enterprises to actively participate in construction of the energy system based on ICT technology. Its objectives not only include guaranteeing stable and efficient power supply through digital networking of the power supply system but also include optimizing the whole energy supply and consumption system by virtue of modern information and communication technology. The E-Energy Plan involve six demonstration projects, including eTelligence, E-DeMa, Model city of Mannheim, MeRegio, "intelligent watt" system and Harz Mountains.

2.3. Japan

2.3.1. Energy policies of Japan

The guiding ideology formed in long-term practice of energy revolution of Japan is the "3E+S" principle, namely energy stability is taken as the premise, energy security is put in the first place, environment suitability is realized while achieving improvement of the economic efficiency and low costs (i.e. balance and uniformity of safety, stability, efficiency and environment suitability).

The Japanese government released the "fifth basic energy plan" in July 2018 and put forward the new objective, route and direction for 2030-2050 energy transformation strategies. Specifically, the following six aspects are involved:
• By 2030, its power structure will be optimized, namely the renewable energy will account for 22-24%, nuclear power will account for 20-22%, and thermal power will account for 56%.
• The emission of greenhouse gases will be reduced by 26% in 2030 compared with 2013, and 80% by 2050, so as to achieve the new goal of "low carbon" to "decarbonization".
• Position the renewable energy as the "main energy resource" in 2050.

2.3.2. Energy internet practice in Japan

Driven by relevant energy policies, markets and reforms, Tokyo Electric Power Company (TEPCO) accelerated its transformation to an integrated energy service provider. On the basis of making traditional energy services bigger and stronger, TEPCO planned ahead of time, made extensive layout, strove to be the leader of market and technology. And it has become a typical representative of international advanced integrated energy service enterprise. In the early stage, TEPCO, through its customer service company to carry out integrated energy service business with other energy enterprises in the country jointly, which mainly provided one-stop services for power and gas as well as other energy solutions. After Japan opened its power retail market fully in 2016, TEPCO restructured its business in line with the trend, built up the strategic position of integrated energy service provider, and established a new professional company. It strove to provide a variety of power energy products and new energy services, and become a leader in the comprehensive energy service industry.
3. Domestic Energy Internet Engineering Practice

3.1. Beijing Yanqing Energy Internet Project

3.1.1. Project overview
Beijing Yanqing Energy Internet Project is located in the high-tech industry incubator of new energy industry base in Badaling Economic Development Area, Beijing. The incubator covers an area of 100mu, with a total construction area of 72,000 m². The project is invested jointly by the National Energy Administration, Beijing, and Yanqing County. It is the first large-scale regional energy internet demonstration project led by the government in China. The total investment of the project is about RMB 126 million, including one 10kV switching station, three distribution rooms and 24 building energy houses. Connecting to the 10kV power grid of the upper level through the existing distribution network, and the total transformation and distribution capacity of the microgrid is 5,500KW.

3.1.2. Technical scheme
Beijing Yanqing Energy Internet Project consists of ten subsystems: intelligent microgrid distribution and transformation system, small wind power generation demonstration system, electric vehicle photovoltaic charging demonstration station, comprehensive energy storage system, high-quality power supply system, microgrid control and energy management system, intelligent distribution system, intelligent power system, two-way communication system, intelligent grid dispatching and park energy service center.

The regional energy internet fully demonstrates the advanced concepts and technologies of green energy, high reliable power supply and intelligent power consumption. Build integrated intelligent microgrid control and energy service center and exhibition center to realize optimization and adaptive interactive control of all links, as well as intelligent and efficient use of electricity. To provide customers with an all-round integrated energy solutions in the future, to realize energy-saving and consumption-reducing in an all-round way for customers, and to provide efficient, intelligent, safe and low-energy consumption integrated energy services with playing a good role as a model.

3.2. Beichen National Industry-City Integration Demonstration Area Energy Internet Project

3.2.1. Project overview
The integrated energy demonstration project of Beichen Business Center Office Building serves the Beichen Business Center Building (which is the location of the Management Committee of Beichen Economic and Technological Development Area). In this area, five systems including solar photovoltaic power generation, wind power generation, solar energy storage microgrid, ground source heat pump, electric vehicle charging pile and an integrated energy intelligent management and control platform have been built. The integrated energy demonstration project of Beichen Business Center Building was started in Nov. 2016 and put into operation in May 2017. At present, it is in good operation, realizing the interconnection and complementarity of various energy sources, optimizing regulation of management and control platform, with an energy efficiency ratio of 2.38 and an increase of 19% in the comprehensive energy utilization efficiency.

3.2.2. Technical scheme
According to the construction idea of "two levels, three layers and four centers", build an integrated energy service management platform to provide users with multi-objective and optimized integrated energy services, such as economic, energy saving, environmental and ecological integrated energy services. "Two levels": The overall design, layered construction, to create a two-level platform at the regional and user levels. "Three layers": Taking the integrated energy service management platform as the material basis, the communication information network as the neural system, and the multiple big data center as the intelligent intermediate hub, to construct the integrated energy service management
platform. "Four centers": Monitoring center, dispatching center, energy efficiency center and trading center.

4. Domestic and Foreign Energy Internet Construction Experience Analysis

4.1. Key technical level

4.1.1. Energy discretization virtual optimization and balance technology
In the German E-Energy pilot project, with the aid of ICT technology to realize the virtual optimization aggregation of interruptible load with long space distance (cold storage), new energy power generation, pumped storage power station and new energy power generation, power generation and user terminal power equipment room and micro-cogeneration system. That disperses the balance that needs to be completed at the unified scheduling level in the virtual bottom layer to complete the optimization, and provides a relatively stable output curve for the scheduling, so as to form a win-win situation of the three parties.

4.1.2. Use the energy storage technology to achieve time shift of energy consumption
Energy internet projects such as the pilot project in the Hartz Mountains in Germany and Beichen National Industry-City Integration Demonstration Area in China have all allocated energy storage to realize the time shift of energy consumption. Electric vehicles, batteries and other energy storage equipment complete the energy consumption within a reasonable price range, and release in the peak price range, so as to realize the time shift of energy consumption and change the time distribution characteristics of energy consumption.

4.1.3. Use ICT technology to promote the integration of various energy flow information
According to the construction experience of the United States, Germany and Japan as well as the pilot experience of China, the construction of regional energy internet needs to focus on the use of ICT technology to promote the integration of various energy flow information. Through intelligent meter, induction technology and communication protocol integration technology to integrate the information of various energy metering equipment and energy consumption terminal equipment. And the price signal is used as a lever to achieve optimization of the application of various energy sources at the user end, to achieve the conversion of energy flow.

4.2. Operation mode level

4.2.1. Various forms of investors stimulate market activity
Germany and the United States have formed the electricity market since the 1990s. There were many kinds of investment forms in the market, and the power, heat, cold and other energy can be operated by a company. This market mechanism is easy to realize the economic optimization and utilization of multi-energy resource in the end-users with the aid of ICT technology, to realize the mutual substitution and transformation of energy, and to form an active market. Since the new round of electric power system reform in China, the construction of electric power market has also achieved initial results. The construction of regional energy internet should be combined with the development process of electric power market to give full play to the advantages of complementary integration of various types of energy.

4.2.2. Subsidies, price adjustment and capacity are linked to guide the orderly development of the market
The adjustment of distributed energy subsidies and prices in Germany is not fixed in a certain proportion in a year, but is combined with the level of energy installed capacity. This approach is conducive to regulating the development speed by economic means. And due to the capacity of
distributed generation connected to the grid and the capacity that the grid can accept need to keep matching, using installed capacity instead of fixed year as the regulation index is conducive to the overall coordinated development of the system.

5. Conclusions
This paper mainly summarizes the current situation of energy internet project practice at home and abroad, and provides relevant suggestions for the construction of regional energy internet in China based on the practical experience. The United States, Germany and Japan are selected from abroad, and the paper introduces their energy structure, energy and power development path and specific project practice conditions respectively. In China, the paper selects three typical energy internet pilot projects: Beijing Yanqing Energy Internet Project, State Grid North Customer Service Center and The Integrated Energy Demonstration Project of Beichen Business Center Building, sorts and analyzes from three aspects: project overview, technical scheme and benefit analysis. Finally, the paper provides experience summary and suggestions for the construction of the regional energy internet. In terms of key technologies, energy discretization virtual optimization and balance technology as well as energy storage technology should be developed. In terms of operation mode, various forms of investors should be encouraged to stimulate market activity and reflect the energy value reasonably; as well as the orderly development of the market can be guided by linking with subsidies, price adjustment and capacity.

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