Typical practice of digital management in electrical industry: Characteristics and Cases of International Energy Internet Practice

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Abstract: Energy Internet is a typical practice of digital management in electrical industry. Energy Internet has formed successful experiences in developed countries, such as Germany, Italy, Denmark, the United States, and Japan. The development process of international energy Internet has been sorted out in this paper is to make reference for the development of energy Internet in other countries. The energy Internet practice exploration of typical countries has been summarized, which is based on their national conditions and their energy system characteristics. The energy Internet demonstration projects in various countries and the energy Internet business carried out by typical enterprises have been studied in this paper.

Keywords: Digital Management, International Energy Internet, Development Practice.

1 INTRODUCTION

Energy Internet is centred on the power system, based on the smart grid, and linked by the Internet, big data, cloud computing, and other latest communication technologies [Tian 2015]. As a new generation of the energy system that comprehensively utilizes power electronics technology and intelligent management technology, Energy Internet can achieve a high degree of integration of energy and information with horizontal multi-source complementarity and vertical coordination of optimization of source, network, load and storage.

Energy Internet is an advanced stage of energy system development, and it is particularly critical and urgent to promote the construction of a clean, low-carbon, safe and efficient energy system. At present, the energy Internet has formed practical cases and successful experiences in Europe, the United States, and Japan. Chinese energy companies such as State Grid, China Southern Power Grid, and China Huadian Corporation LTD. have also started practical explorations in some areas, and some pilot projects have been put into operation [Dong 2014, Wang 2018].

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1.1 Characteristics of Energy Internet Development Practice

The development of the international Energy Internet is in its initial stage. The exploration of each country focuses on its national conditions and energy system characteristics and has not formed a unified Energy Internet development model [Wu 2016, Cao 2014].

In terms of development direction, different countries have a highly unified understanding of the basic characteristics of energy Internet, such as multi-energy coupling, flat and decentralized, and high-proportion renewable energy access, such as resilient energy Internet in the United States, the industry coupling energy Internet in Germany, the hydrogen energy Internet in Japan, and the regional energy Internet based on heating technology in Denmark [Yu 2016].

In terms of technological progress, the innovative application of new technologies and elements is valued, including advanced regional cogeneration, hydrogen fuel cells, the Internet of Things, energy blockchain, virtual power plants, etc. Among them, regional cogeneration technology and hydrogen fuel cell technology have achieved good application effects.

In terms of development practice, energy Internet demonstration projects generally focus on the user side, focusing on advanced concepts, key technologies, and elements of regional energy Internet, all of which are combined with national conditions, concepts, and technologies, such as EUREF Campus, EnergyLab Nordhavn project in Denmark, Harumi Olympic Village in Japan [Feng 2017, Wang 2017, Zhao 2020].

1.2 Contents of this paper

The development process of international energy Internet has been sorted out in this paper. The energy Internet practice exploration of typical countries has been summarized, which is based on their national conditions and their energy system characteristics, as shown in Table 1. The energy Internet demonstration projects in various countries and the energy Internet business carried out by typical enterprises have been studied in this paper.

Table 1: The development process of international energy Internet.

Countries	Cases
Germany	EUREF Campus
Denmark	The EnergyLab Project
Italy	Enel
the United States	Auto Grid
Japan	Kansai Electric Power Co., Ltd.

2 Development of Energy Internet in Europe

2.1 Overview of Energy Internet in Europe

Developed countries have started building the energy internet at an early stage, with Europe being the first to propose and implement it. It has invested heavily and developed rapidly. Under the EU's fifth, sixth, and seventh frameworks, European countries have conducted research work on energy co-optimization, integrated energy systems, and other related aspects.

At the same time, they have also carried out a large number of in-depth studies on comprehensive energy development based on their own needs. The development of the European energy internet requires the participation and cooperation of governments, enterprises, academic institutions, and the public at large. Currently, the EU has proposed a series of policies and action plans to promote the development of the European energy internet, such as the “2030 Climate and Energy Framework” and the “European Clean Energy Plan.” Many European countries are also actively exploring and practicing relevant technologies and policies, such as Germany's “E-Energy” project and France’s “Econetworks” project.

The UK government has been promoting the development of the energy internet by implementing policies and plans to encourage innovation and growth in this field. For example, the UK government launched the Energy Transformation Plan in 2019, which aims to increase the share of renewable energy in the country's electricity mix to 40% by 2050. In addition, the UK government has launched several programs to support clean energy development, such as carbon reduction plans and renewable energy funds.The UK is also making significant technological advancements in the energy internet. For example, National Grid, the UK's largest utility company, is researching and developing smart grid technology to achieve more efficient energy distribution and management. Additionally, UK-based start-ups are developing new energy internet technologies, such as blockchain-based energy trading platforms.

From the perspective of pilot projects promoted in EU member states, Germany is the most representative. Germany's practice mainly relies on two "four-year plans", namely the "Future Energy System" project from 2008 to 2012 and the "Smart Energy-Energy Digital Transformation" demonstration project (SINTEG) from 2016 to 2020. Among them, "Future Energy System" E-Energy is a landmark project. After the implementation of E-Energy project, the German government has also promoted projects such as IRENE, Peer Energy Cloud, ZESMIT, and Future Energy Grid.

Germany is a major energy consumer with relatively scarce oil and gas resources. Since the 1990s, it has made reducing dependence on imported energy a key task of its energy strategy, actively promoting energy demand reduction and increasing energy efficiency while developing renewable energy sources to achieve carbon-free energy supply. Germany is one of the earliest countries to explore and practice the energy internet, focusing on digital transformation of the entire energy system to promote the development and utilization of renewable energy sources, thereby promoting energy structure transformation and energy efficiency improvement.

Under the guidance of government departments, Germany has conducted two series of pilot projects in stages, initially exploring and testing the potential and implementation methods of information communication technology for coupling, interconnecting, and trading different energy systems. The E-Energy project launched in 2008 has comprehensively explored the market, technology, and system levels of information and communication technologies that drive the coupling, interconnecting, and trading of different energy systems. The C-sells project launched in 2012 is part of the SINTEG plan and aims to create small digital energy interconnection systems to achieve regional micro-balance and optimization of energy production and sales.

2.2 Cases of Energy Internet in Europe: EUREF Campus, EnergyLab Nordhavn and Enel

EUREF Campus, located in the southwest of Berlin, Germany, is a pilot dedicated to implementing advanced concepts of energy transformation. 80%-95% of the energy needs of the entire pilot are met by renewable energy sources such as wind power, photovoltaic, geothermal, and biogas. Through technologies such as smart microgrid systems, ultra-low energy buildings, and IoT-based control systems, the efficient use of renewable energy is realized, intelligent charging and discharging of electric vehicles, flexible conversion of hot and cold energy storage, and convenient energy transactions.

The EnergyLab Project in Nordhavn, Denmark, is deeply participated by ABB and the Danish University of Science and Technology, which focuses on the practice of several key technologies and concepts, including regional low-temperature heating technology to achieve deep interconnection of electric heating networks, energy service-oriented flexible management platform, Intelligent control of buildings for flexibility. This project has installed intelligent collection and control equipment in 19 apartments in the area. Through the intelligent control of the electrical equipment (mainly air conditioners and heat pumps), it has realized the improvement of system adjustment benefits, the reduction of user energy costs, and energy conservation and emission reduction. In terms of system conditioning benefits, these homes reduced morning peak loads by an average of 68%. In terms of energy-saving benefits for users, the average heating cost is reduced by 15%, and the energy-saving benefits are significant. In terms of system economy and environmental protection, it saves 600,000 DKK and reduces CO2 emissions by about 70t per year.

Enel in Italy covers power generation, transmission and distribution, power trading, gas transmission, gas storage, gas sales, and smart energy services. Its business sectors include global infrastructure and power networks, global trade, and global power production. Affected by the electricity marketization reform carried out in Italy since 1999, Enel divested its power transmission business, focused on its main business, and looked for new business growth points. To meet the Kyoto Protocol and EU 2050 Low-Carbon Economy Roadmap, EGP was established in 2008 to carry out the acquisition, development and management of global renewable energy. In 2009, Enel took precautions to build an urban intelligent lighting system; under the environment of continuous strict control, it increased the development and investment in emerging integrated energy services such as electric vehicles, energy storage, and smart cities. In 2016, Enel cooperated with AWS to realize all the applications online. In 2017, EneX was established to operate independently, providing digital value-added services for industry and commerce, transportation, cities and families. It acquired several companies including EnerNoc and quickly formed a healthy development trend. In 2020, build a digital middle platform and realize the output of standardized products and services related to the user side.

3 Development of Energy Internet in the United States

3.1 Overview of Energy Internet in The United States

The US Department of Energy (DOE) is the highest authority for various types of energy resources in the US and is responsible for developing related energy policies. The US Energy Regulatory Commission is responsible for implementing government energy policies and suppressing the random fluctuations of energy prices. Under this management mechanism, various energy systems in the US have achieved better coordination and cooperation. Meanwhile, typical integrated energy suppliers such as PG&E and Edison Electric have developed well.

The US government has been promoting the development of energy internet through policy and plan formulation to promote innovation and development in this field. In 2015, US President Barack Obama signed the Clean Energy Plan to promote the development and utilization of clean energy, including strengthening the construction of smart grids, promoting distributed energy, and other measures. In addition, the US government has launched a series of plans to support the development of clean energy, such as renewable energy funds, carbon reduction plans, etc. The technology of US energy internet is also constantly improving. For example, the US has started to build decentralized energy trading platforms based on blockchain technology to achieve transparent and secure energy trading and settlement. Tesla is researching and developing advanced battery technology and energy storage solutions to support the development of the electric vehicle market. In addition, some companies are also developing intelligent meters, smart homes, and other products to improve the efficiency and convenience of energy use.

The US already has some practical cases that demonstrate the feasibility and advantages of energy internet. For example, California has established a smart grid project called “CaliSmart” that achieves real-time monitoring and control of the power system, improves the reliability and efficiency of power supply. In addition, states such as Florida and Texas are actively exploring the application of distributed energy and microgrid technologies.

3.2 Cases of Energy Internet in The United States: Auto Grid

Auto Grid in the United States mainly involves big data of energy. The business content includes energy consumption prediction, optimized operation, and demand management. Its development strategy is to create a brain for smart meters. Demand side products include electricity consumption forecast, combined with electricity price to realize demand response and demand side management analysis; smart home products mainly include demand response management, power generation and grid dynamic load prediction and grid operation fault prediction. Auto Grid has established an energy data platform architecture online, and has specially established a public facility backend. It collects and analyzes the data on the energy demand side (industry, enterprises, and residents) through the Demand Response Optimization and Management System (DROMS), and these data were uploaded to the Energy Data Platform (EDP) for analysis, prediction and storage online. The business model includes a SaaS model, shared revenue model and cooperation model. Among them, the SaaS model is that users pay according to the amount of data processed by Auto Grid; the shared revenue model refers to that Auto Grid sends reports to customers, the customer responds to demand,

and shares revenue with customers; the cooperative model refers to providing software to equipment manufacturers, and charge the equipment manufacturer a license fee.

4 Development of Energy Internet in Japan

4.1 Overview of Energy Internet in Japan

Japan is a highly developed industrialized country and also a major energy consumer. With the continuous growth in energy demand and increasingly serious environmental issues, the Japanese government has started to pay attention to the development of energy internet and has taken a series of measures to promote its development. The Japanese government has promoted the innovation and development of energy internet through the formulation of relevant policies and plans. In 2017, the Japanese government released "Smart Society Strategy" and "Green Future Strategy", proposing measures such as promoting smart grids and renewable energy. Japan also has certain accumulation and advantages in energy internet technology. Japan has built a series of infrastructure, such as intelligent meters and electric car charging stations, and actively develops advanced battery technology and energy storage solutions. Many Japanese companies have also started to invest more in the field of energy internet. For example, Tokyo Electric Power Company is developing a decentralized energy trading platform based on blockchain technology, and Toyota Motor Corporation is also researching and developing new energy vehicle technology. Japan also actively participates in international cooperation, working with other countries to promote the development of energy internet. Japan has signed multiple cooperation agreements with countries such as the United States and Europe to jointly promote research and development in areas such as smart grids and electric vehicles.

4.2 Cases of Energy Internet in Japan: Kansai Electric Power Co., Ltd.

Kansai Electric Power Co., Ltd. of Japan covers power, gas, communication and livelihood business service, and its customer groups include large industrial and commercial users, small commercial and household users, etc. Before 2015, Kansai Electric Power mainly focused on the power industry, and the other three sectors (IT, integrated energy supply and livelihood services) were relatively independent business sectors. With the gradual opening up of the electricity retail market, the electricity and gas sales business has been impacted. In 2016, K-Opticom, a communications company under the Group, sold a bundled package of communication and electricity services. In 2018, the Group launched the electric package Nattoku Pack, an electric co-sale package. The Group began to integrate its business, and initially formed a business model with the integrated energy supply of electricity and gas as the core, integrating with the other three sectors and growing together. Driven by the 5D phenomenon of the big social environment, the Group proposed an overall strategy driven by digital transformation, and established a new joint venture company k4 digital with Accenture in due course to promote the transformation.

5 Conclusion

To sum up, the development of the energy Internet in Europe, the United States and Japan mainly adopt top-down promotion. The summary in this paper will provide targeted reference for the development of energy Internet for other countries. In the process of promotion, industry guidance and policy support at the national level are indispensable, focusing on the practical exploration of highlighting key links, core concepts and key technologies, and based on extensive use of Internet technology, they have conducted in-depth cooperation with professional energy data analysis companies.

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