Analysis of the Researching Status for Ubiquitous Power Internet of Things

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Abstract: The construction of ubiquitous power Internet of things (UPIoT) is mainly to apply new technologies and ideas such as information technology and artificial intelligence to the development process of enterprises in order to improve technological level of power enterprises. At the same time, it also serves the national strategic needs and conforms to the strategic requirements of promoting the integration of Internet, big data, artificial intelligence, and manufacturing industry. It is significant to promote China's scientific and technological development, industrial upgrading, and improve people's living standards. This paper first briefly introduced the background, construction goals, and significance of UPIoT. Then, it discussed the attitudes and corresponding measures of some communities towards UPIoT. Afterwards, it illustrated the typical application of UPIoT at present, and lastly the possible problems in the development process of UPIoT were analyzed.

Keywords: Ubiquitous power internet of things (UPIoT); Internet of things; Energy internet; Three types and two networks; Virtual power plant

1. INTRODUCTION

The concept of the Internet of Things (IoT) was first proposed by Professor Kevin Ashton, co-founder of the Automatic Identification Center at the Massachusetts Institute of Technology in 1998 [1]. He pointed out the application of radio frequency identification (RFID) and other sensor technologies in everyday objects to construct an Internet of Things. The understanding of "Internet of Things" in the power industry is that it is a network system that brings about the identification, perception, interconnection, and control of power grid infrastructure, personnel, and the environment they are in [2]. The "ubiquitous Internet of Things" refers to the information connection and interaction between any time, place, person, or object. The ubiquitous power Internet of Things (UPIoT) is a new concept first proposed by the Chairman of State Grid Corporation of China, Kou Wei, at the teleconference on the deployment of IoT construction work for State Grid Corporation of China held in Beijing on March 8, 2019 [3,4]. It is the specific manifestation and application implementation of "ubiquitous IoT" in the power industry. It is not only an innovation in technology, but also an innovation in management concepts and thinking, with a focus on improving quality and efficiency internally. The external focus is on integrated development.

2. OVERVIEW OF UBIQUITOUS POWER IOT

2.1. BACKGROUND OF THE PROPOSAL OF UBIQUITOUS POWER IOT

From the perspective of the country, building the

ubiquitous power Internet of Things is a specific practice of State Grid Corporation of China's strategy in building a strong network. It is an important measure to implement the central deployment and play the leading role of central enterprises, and it is an inevitable requirement for it to adapt to internal and external situations and challenges. From the perspective of State Grid Corporation of China, facing the challenges of marketization, we are seeking strategic transformation and making a comprehensive promotion of the construction of "three types and two networks," accelerating the strategic deployment of building a world-class energy internet enterprise with global competitiveness, which is one of its specific measures. From the perspective of service recipients, in the past decade or so, China's economy has developed rapidly. Correspondingly, the demand for electricity from power grid service recipients such as enterprises and residents has increased sharply, and the demand patterns have also become diversified. The current technological level and management mode of the power grid are no longer optimized, making it difficult to perfectly meet the requirements of all parties. Power grid enterprises need to shift from engineering-driven to customer value-driven [5]. It is imperative to achieve a "customized" solution that meets the customer needs, namely the construction of ubiquitous power IoT.

2.2. THE CONCEPT AND CONSTRUCTION SIGNIFICANCE OF UBIQUITOUS POWER IOT

The ubiquitous power Internet of Things (IoT) refers to a smart service system that fully utilizes modern information technologies such as mobile internet and artificial intelligence, as well as advanced communication technologies, to achieve the interconnection and human-machine interaction of all aspects of the power system. It has the characteristics of comprehensive state perception, efficient information processing, and convenient and flexible application [6], mainly consisting of four layers: perception layer, network layer, platform layer, and application layer [7].

The construction of the ubiquitous power Internet of Things is of great significance in both technical and business aspects. In terms of technology, the construction of the ubiquitous power Internet of Things can promote the deep integration of the power grid and the Internet, apply advanced technologies such as big data and artificial intelligence to the traditional power grid, and bring about the combination of traditional industries and emerging technologies. This can result in more efficient energy distribution, thus avoiding waste, and promoting the Chinese power industry to improve the level of related technologies as a whole, and catching up with and surpassing the Vanguard International Semiconductor Corporation's advanced power enterprises in technology. From a business perspective, building the ubiquitous power Internet of Things is a strategic adjustment of State Grid Corporation of China, moving from natural monopoly to marketization, stimulating enterprise vitality, and building the core competitiveness of energy internet enterprises with "strength and intelligence." On the basis of adhering to the original business, it can build a complete platform centered on electricity, expand business and form an ecosystem, and provide complete and comprehensive electricity related services [5].

2.3. STRATEGIC ARRANGEMENT, SPECIFIC CONTENT, AND STRATEGIC OBJECTIVES FOR THE CONSTRUCTION OF UBIQUITOUS POWER IOT

The strategic arrangement is to designate 2019–2021 as the strategic breakthrough period, followed by several years as the breakthrough period and improvement period. By 2021, the ubiquitous power Internet of Things will be preliminarily established, achieved business collaboration and data connectivity, and unified IoT management. All levels of smart energy comprehensive service platforms will have basic functions to support the development of power grid business and emerging businesses. By 2024, the ubiquitous power Internet of Things will be established, fully achieved business collaboration, data connectivity, and unified IoT management. The company level smart energy comprehensive service platform has powerful functions, and a comprehensive energy internet ecosystem of co-construction, co-governance, and sharing will be formed.

The State Grid Corporation of China's "Outline for the Construction of the Universal Power Internet of Things" points out that the specific construction content includes six aspects: internal business, external business, data sharing, basic support, technical research, and security protection. Specifically, the key directions for internal business are improving customer service level, improving enterprise business performance, improving the safe and economic

operation level of the power grid, and promoting the consumption of clean energy. The key directions for external business are building a smart energy comprehensive service platform, cultivating and developing emerging businesses, building an energy ecosystem, and data sharing and basic support. There are a total of 11 key directions for technical research and safety protection.

Building the ubiquitous power Internet of Things is the core task of implementing the strategic goal of "three types, two networks, and world-class." In this core task, "three types" refer to "hub type, platform type, and shared type," while "two networks" refer to "strong smart grids and ubiquitous power IoT." The ubiquitous power Internet of Things is the second network after the strong smart grid, with diversified and ecological characteristics. The construction goal is to make the ubiquitous power Internet of Things complement and integrate with the strong smart grid, and the two work together to form a powerful value creation platform, jointly forming an energy internet that integrates energy flow, business flow, and data flow.

3. ATTITUDES AND RESPONSE MEASURES OF VARIOUS SECTORS TOWARDS UBIQUITOUS POWER IOT

3.1. ON THE GOVERNMENT SIDE

The government is a major driving force for the construction of ubiquitous power internet. Based on the "Strong Smart Grid and ubiquitous Power Internet of Things = Energy Internet," ubiquitous power Internet of Things can collect and successfully utilize massive amounts of data, achieve data sinking, and establish a powerful data and application platform. From the perspective of energy internet construction, the construction of ubiquitous power IoT is not only a measure taken by State Grid Corporation of China to keep up with the development of the times, but also a response to the national initiative for the development of the energy industry, which is in line with the national development policy and plays a huge role in promoting the construction of China's energy internet.

3.2. STATE GRID CORPORATION OF CHINA

At present, with the rapid development of China's economy and society, the demand for electricity is not only limited to an increase in quantity, but also requires a cleaner source of electricity, with more reasonable and flexible utilization, and avoidance of large-scale waste. To achieve the mentioned requirements, modern information technology needs to be utilized to break through the bottleneck of power development, leading to the emergence of the ubiquitous power Internet of Things. State Grid Corporation of China was the first proposer and participant in the construction of the concept of ubiquitous power Internet of Things. The construction of ubiquitous power Internet of Things is an important content and key link in promoting the construction of "three types and two networks." Building the ubiquitous power Internet of Things can solve the technical problems of the power grid, break through the bottleneck of power grid development, and is also one of the two important links in building the energy internet. It helps to achieve the integration of large-scale distributed power generation systems and distributed energy storage systems, as well as wide area energy sharing based on internet technology, and achieve comprehensive innovation and profound transformation of State Grid Corporation of China. The ubiquitous power Internet of Things will transform power grid companies from traditional power grid enterprises to comprehensive energy service providers, drive collaborative innovation and development of the upstream and downstream industrial chain of power grid enterprises, lead the high-quality construction of the national energy internet, and form core competitiveness at a new and higher level [9,10].

3.3. UNIVERSITIES AND RESEARCH INSTITUTES

Currently, the ubiquitous power Internet of Things is a new research topic for various universities and research institutes, with great research potential and value. It can integrate research results from different research directions, achieve organic integration of energy, information, and communication, and break through the bottleneck of China's current power grid development. At the same time, compared to traditional power grids, ubiquitous power IoT can collect a large amount of data with a wide range, which is very important for research in universities and research institutes. After the proposal of the ubiquitous power Internet of Things, many universities and research institutes have highly recognized it and actively conducted related research. Building the ubiquitous power Internet of Things

requires strengthened communication and cooperation among universities, research institutes, and enterprises, even cross-border cooperation. In April 2019, a well-known domestic university, communication enterprise, and internet enterprise jointly established the Universal Power Internet of Things Industry Alliance. This platform facilitates communication and close cooperation between each other, and utilizes their respective advantageous resources to accelerate the construction of the Universal Power Internet of Things.

3.4. BUSINESS CIRCLES

Many famous entrepreneurs in China highly recognize the construction of the ubiquitous power Internet of Things. They believe that this is not only an opportunity for State Grid to achieve its own adjustment and development, but also a new opportunity for growth that many enterprises can obtain. The arrival of 5G has built the foundation of the Internet of Things and provided tools for the construction of the ubiquitous power Internet of Things. It can effectively stimulate industrial creativity and bring market opportunities to traditional industries such as energy and electricity. Currently, many enterprises in China are actively seeking cooperation with State Grid Corporation of China in the field of ubiquitous power IoT. These enterprises come from different fields and have different business scopes, but their products or services are closely related to people's lives. Their cooperation with State Grid Corporation of China means that the ubiquitous power Internet of Things will change all aspects of people's lives related to electricity.

3.5. OTHER ASPECTS

The biggest difference between ubiquitous power IoT and traditional power grids lies in the use of many modern technologies to expand many new businesses based on the established business scope of "transmission, transformation, distribution, use, sales." The integration of the Internet has made the public more aware of power grid services and provided convenience for their daily use. In the power grid link, the electricity price issue that the public is most concerned about is taken as an example. Currently, most residents use electricity in a hierarchical way. With the establishment and use of the ubiquitous power Internet of Things, big data and artificial intelligence can obtain a more reasonable electricity price calculation method through statistics and analysis of massive data. The public can also learn about their electricity consumption in real-time through the "online power grid." In the comprehensive energy service sector, new technologies can promote the strategic transformation of State Grid Corporation and launch new convenient services. The public also holds a positive and supportive attitude towards the ubiquitous power Internet of Things.

4. TECHNICAL SUPPORT FOR THE CONSTRUCTION OF UBIQUITOUS POWER IOT

The technical support of ubiquitous power Internet of Things mainly includes big data, cloud computing, Internet of Things, mobile interconnection, artificial intelligence, blockchain, edge computing, etc. Communication technology runs through all aspects and is one of the core technologies of the ubiquitous power Internet of Things. It is a fundamental component of achieving the interconnection of all things. Taking communication technology support as an example, the ubiquitous power Internet of Things can be interconnected through different types of communication networks. However, the complexity, inclusiveness, openness, and innovation of the ubiquitous power Internet of Things naturally determine its need for massive data support. A large amount of data is transmitted every moment, and 4G communication can no longer meet its needs. The latest development of 5G communication has unique advantages, such as high speed, capacity, and reliability, as well as low latency and energy consumption, which correspond to the basic needs of the power system, The basic needs include massive data transmission, interconnection of the information of all things, power system reliability, flexible response and collaborative control, and battery life and guarantee.

The parts of the power system that have high requirements for real-time control and reliability must be connected to the power optical fiber private network. Its performance in terms of communication bandwidth, reliability, and communication delay is not lower than 5G communication, while the distributed equipment corresponds to the high-density connection characteristics of 5G communication. At the same time, the data growth

brought by 5G will also promote the improvement of data analysis level such as artificial intelligence, big data and deep learning. 5G communication is significant for the massive access of distributed controllable resources, and the establishment and development of a wide area measurement system [5,6]. 5G can play a supportive role in upgrading and improving various aspects of the power grid. For example, power grid management, user services, and business requirements. Specifically, softening open technology can assist in managing the ubiquitous power Internet of Things, allowing the power grid to have a stronger autonomy in communication. Performance enhancement technology provides technical support for the realization of the ubiquitous Internet of Things in the power industry. Autonomous optimization technology makes the ubiquitous power Internet of Things intelligent, thereby achieving a new business model centered on users, comprehensive state perception, efficient information processing, and convenient and flexible application. Hence, 5G communication is one of the key technical support for achieving the ubiquitous power Internet of Things, which requires network operators to accelerate the construction speed of 5G, expand coverage area, stabilize signal strength, and accelerate the optimization of the technologies required for the ubiquitous power Internet of Things, in order to achieve integration with the ubiquitous power Internet of Things [11].

5. APPLICATION OF UBIQUITOUS POWER IOT

5.1. APPLICATION IN THE FIELD OF TRADITIONAL POWER GRIDS

In the field of traditional power grids, the application scenarios of ubiquitous power IoT are divided into collection and control categories. Among them, the collection category refers to the detection and collection of various parameters of the tested object, which are converted into digital signals and sent to a computer for storage, analysis, and processing, including advanced metering, smart grid large video applications, etc. Control category refers to the control of the execution mechanism of a system through output signals, including demand side response of electricity loads, distributed energy regulation, etc. In the ubiquitous power IoT application scenario, collection applications can achieve higher collection frequency, richer and more comprehensive content, and two-way interaction. The control field will switch from the current star centralized connection mode to the point-to-point distributed connection mode, and the master station system will gradually sink, with more local nearby control and edge computing [8].

5.2. APPLICATION IN EMERGING FIELDS

In emerging fields, the ubiquitous power Internet of Things will play a significant role in clean energy consumption, comprehensive energy service platforms, information sharing, multi-scenario security protection, and multi-site integration, thereby empowering power grid enterprises and emerging business entities. Taking the comprehensive energy service platform and multi-site integration as an example, the comprehensive energy service platform is a new type of energy service method that meets the diversified energy production and consumption of end customers. It is user-centered, which centered around demand response, energy efficiency management, and power trading, shifting from traditional electricity supply to comprehensive energy supply of cold, heat, electricity, and gas, and fully utilizing technological advantages to provide customers with matching services [8,9]. Multi-station integration is the expansion and integration of distributed new energy power stations, 5G communication base stations, and environmental monitoring stations. It is based on the integration of traditional substations, energy storage stations, and data center stations, to achieve cross-border integration in business, open sharing of data, and improve energy utilization efficiency [12–15].

5.3. TYPICAL APPLICATIONS OF THE INTERNET OF THINGS IN THE POWER INDUSTRY

China is the first and only country to put forward the concept of ubiquitous power Internet of Things. Currently, one of the typical applications of ubiquitous power Internet of Things in China is “virtual power plant.” “Virtual power plant” is proposed to integrate distributed generation, controllable load, energy storage devices, and other energy sources that are not easy to control and easily wasted in the past, so as to improve the utilization rate of electric energy. The essence of “virtual power plant” is a distributed power management

system. Through this system, distributed power sources, controllable loads, and energy storage devices in the power grid are aggregated into a virtual and controllable collection of power sources, instead of being completely isolated and dispersed. They then participate in the operation and scheduling of the power grid, intelligently coordinating the contradiction between smart grids and distributed power sources, and bringing maximum economic and social values to the power grid and users through distributed energy. The power generation system, energy storage equipment, and communication system organically form the whole "virtual power plant." The "virtual power plant" is not a real power plant, but rather an "intelligent steward" of electricity. It is a decentralized energy aggregation formed by modern technology. When distributed energy such as photovoltaic is intermittent, it is organized through energy storage devices to form a stable and controllable "large power plant." Each small component of the "large power plant" is geographically dispersed. However, it is scheduled and utilized as a whole through transmission lines and communication systems [16].

The technology of "Virtual power plant" is still in continuous development, and its subversive effect on the future energy market has been revealed from its current practical application. This effect is reflected in the fact that power generation and power consumption cannot be perfectly matched every moment. Before the "Virtual power plant" appeared, there was an irreducible contradiction between the two, which not only caused energy waste, but also caused security problems. The "Virtual power plant" can precisely control the balance between power demand and power generation output.

The most important thing to achieve "virtual power plant" is the support of big data. Only massive data can achieve accurate control, and the ubiquitous power Internet of Things can collect sufficient and effective data, thus laying a data foundation for the realization of "virtual power plant." In China, "virtual power plant" supported by big data will be built in Shanghai and Jiangsu. In abroad, Shell is building "virtual power plant" supported by big data in the UK, and Tesla is building "virtual power plants" in Australia.

There are also many explorations in smart grids, the Internet of Things, and other fields abroad. Although they have not explicitly proposed the concept of "ubiquitous power Internet of Things," they have applications that have the same or similar functions. Moreover, due to differences in geographical location, development status, and challenges faced by different countries, the focus of the power industry on IoT applications varies among different countries. For example, the European power industry tends to focus more on clean energy and environmental protection, while the Japanese power industry tends to monitor and predict new energy generation, smart meter metering, and more on IoT applications in micro network system monitoring and other fields [17]. The following examples illustrate specific applications.

In the Western European region, in order to achieve the goals of reducing carbon dioxide emissions and energy consumption, Amsterdam in the Netherlands has applied energy-saving smart technology to two projects, West Orange and Geuzenveld. In addition, there are intelligent building projects that can analyze historical data on the energy use of the building without affecting the normal commercial and living functions of the building, achieving the lowest energy consumption and effective operation of the power system.

In the North American region, the Debbie City government in the United States is collaborating with International Business Machines Corporation (IBM) to address the issues of lack of coordination and high costs in operating independent systems covering various resources in the city, such as water supply systems, power systems, oil, natural gas, transportation, and public services. They plan to use Internet of Things technology to connect each independent system to form a digital system covering various resources in the city, monitoring various data analyzing and integrating to intelligently respond to the needs of citizens. This not only enables them to enjoy more satisfactory services, but also reduces urban energy consumption [18].

6. ISSUES THAT MUST BE CONSIDERED AND SOLVED IN THE CONSTRUCTION OF UBIQUITOUS POWER IOT

6.1. INFORMATION ACCURACY AND SECURITY ISSUES

In the process of ubiquitous power IoT construction, it is necessary to collect and analyze massive amounts of data,

which cover a wide range and relate to various information of Chinese citizens. Whether from the perspective of national defense or other aspects, preventing information leakage is the most important issue, and having a safe and reliable information protection system is a necessary condition [8,19–21].

6.2. STRATEGIC RESEARCH QUESTION

The ubiquitous power Internet of Things is emerging, and its related concepts and applications may need to be improved. Moreover, communication technology and application environment are rapidly changing. Therefore, in terms of strategy, it is necessary to consider the compatibility between long-term and short-term strategies, and investment issues worth studying, in order to try to avoid excessive waste [22].

6.3. CONSTRUCTION INTENSITY OF THE STATE GRID

Construction intensity of the State Grid is not as expected. A strong smart grid constructed by ultra-high voltage, rural power grid, and distribution network is still under construction, and its construction progress and investment may affect subsequent investments in the ubiquitous power Internet of Things [20].

6.4. INDUSTRY BARRIER ISSUE

The ubiquitous power IoT created by State Grid Corporation of China is an open platform that involves many industries. Undoubtedly, the ubiquitous power IoT is centered around the power grid, thus when competing with traditional information industries, it may face their impacts directly. A lack of relevant experience is a problem [23].

7. CONCLUSION

This article mainly introduced the concept, objectives, significance, and strategic arrangements of the ubiquitous power Internet of Things, and summarized the views of various sectors on the construction of the ubiquitous power Internet of Things from different perspectives. The measures that will be taken and the technical support required during the construction process were analyzed. Lastly, based on the characteristics of the ubiquitous power Internet of Things, the scope of its application was analyzed, and the risks and problems that must be faced during the construction process were listed. In summary, the construction of the ubiquitous power Internet of Things is an important step taken by State Grid Corporation of China in its development process, achieving effective aggregation of distributed new energy, and upgrading of distribution systems. It is not only an important part of complying with national development and building a national energy internet, but it also deeply affects the development process of China's power industry. Plus, it promotes enterprise technology upgrading and opens-up new businesses, and changes people's daily electricity consumption methods.

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