Research on the development of photovoltaic informatization based on ubiquitous power Internet of things

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Abstract. The Internet of things integrates traditional technologies with communication, information, sensing and other technologies to achieve comprehensive perception, intelligent processing, reliable transmission of traditional physical facilities. Photovoltaic power application market has developed over a decade, with a continuously expanding installed scale and the conditions of grid parity have been provided preliminarily. In this paper, photovoltaic distribution is proposed to replace large centralized ground power stations in the future and become the main force of photovoltaic power generation. In addition, intelligent photovoltaic Internet of things (iot) system with comprehensive perception, cloud-side collaboration and whole-process data sharing and integration is designed.

1. Introduction

With the State Grid Co., ltd. putting forward the construction and operation of "strong smart grid" and "ubiquitous power Internet of things" and emphasizing the overall arrangement of the construction of ubiquitous power Internet of things, accelerating the implementation of the strategy of "Three types, two networks, World-class" is gradually affecting the development of the entire power industry. Photovoltaic power application market has developed over a decade in our country, with a continuously expanding installed scale and the conditions of grid parity have been gradually provided. The comprehensive perception, intelligent processing and reliable transmission of photovoltaic data will be fully carried out in the industry.

At present, the industry has also carried out photovoltaic data collection and monitoring technology research. The IEECAS (Institute of Electrical Engineering of the Chinese Academy of Sciences) cooperated with Japan to build 16 photovoltaic power stations with a total capacity of 128Kwp for schools without electricity. Each power station is equipped with data collection and monitoring system, and the data is stored on IC CARDS, which are changed regularly. Based on ZKwp wind/light complementary power station, IEECAS developed a set of real-time monitoring system based on CP machine with the application of Labview technology. ZOKWp grid-connected photovoltaic power station built by Beijing Jike (Beijing Jike Energy New Technology Development Company) has developed a set of photovoltaic power station data acquisition and monitoring system. HUAWEI focuses on standardizing the transmission protocol and enhancing the function of communication software. The photovoltaic field station monitoring system developed by GUODIAN ZHISHEN has realized large-scale data collection. However, there are still some problems in efficient data collection and storage, such as lack of collection, numerous protocols and weak signals.

According to the construction idea of ubiquitous power Internet of things, based on the development status of photovoltaic power generation industry, this paper presents the largest
photovoltaic cloud platform technology in China, and puts forward the prospect of photovoltaic power generation Internet of things construction.

2. The origin of ubiquitous power Internet of things
IOT (Internet of things, IOT) was first put forward by the Massachusetts institute of technology professor Kevin Ashton. As its concept and connotation kept developing, the current accepted definition is that based on the information carrier such as the Internet, radio and television network, the traditional telecommunication network, the Internet of things is a network that enables all ordinary physical objects to be independently addressed to achieve interconnection and interoperability. Its core technology system includes equipment coding technique, equipment identification technology, communication technology, sensor technology and encryption technology, etc.

In 2010, China began to study the basic theory and application technology of power Internet of things. Power Internet of things is the application of Internet of things in smart grid, which is mainly divided into five layers: power grid layer, perception layer, transmission layer, service layer (data layer) and application layer. The Internet of things integrates traditional technologies with communication, information, sensing and other technologies to achieve comprehensive perception, intelligent processing and reliable transmission of traditional physical facilities. Comprehensive perception allows physical facilities to be identified and collect dynamic information anytime and anywhere by means of RFID, sensors and QR codes. Intelligent processing analyses and manages through cloud or end-to-end intelligent algorithms. Reliable delivery means delivery via wired network or 5G.

The ubiquitous power Internet of things put forward by State grid co., LTD. is an evolved form of power Internet of things. Its infrastructure is consistent with the power of things. It is an intelligence service system which can implement interconnection of each link of power system and human-computer interaction, and has the function of comprehensive information awareness, efficient processing, and flexible application via fully application of modern information technology such as mobile communications, artificial intelligence, advanced communication technology over every link of power system. "Ubiquitous" refers to the information connection and interaction between any time, any place, any person and anything. "Ubiquitous power Internet of things" connects power users and their equipment, power grid enterprises and their equipment, power generation enterprises and their equipment, suppliers and their equipment, and people and things, and serves users, power grid, power generation, suppliers and government society by generated shared data. The ubiquitous power Internet of things takes the power grid as the hub, plays the role of platform and sharing, creates greater opportunities and provides value services for the development of the whole industry and more market players.

3. Sensing based on ubiquitous power Internet of things
From the technical point of view, the ubiquitous power Internet of things includes four layers: perception layer, network layer, platform layer and application layer. The construction content of internal and external business is carried through the application layer; the construction content of data sharing and foundation support is carried through the perception layer, network layer and platform layer; and the construction content of technical breakthrough and security protection runs through all layers.

The terminal sensing node of the perception layer has a larger scale and more comprehensive data collection, covering all links, equipment and even components of the power system in power generation, transmission, distribution, storage and application. The network layer will realize higher data transmission efficiency through the application of new technologies such as 5G. Platform layer will unify the collection and management of all data, and data barriers will be broken down. The application layer collaborates with the construction of intelligent service system to provide users with more intelligent and humanized universal power services and reflects the value of data.
In the ubiquitous power Internet of things, each sensing node will share relevant information flow. For example, under a centralized spectrum sensing condition, there are N cognitive sensing nodes and 1 fusion center. Each sensing node makes a decision on the spectrum utilization of the main user and sends it to the fusion center. The fusion center obtains the result of whether the final spectrum is free or not through the "or" rule and returns it to the sensing nodes. During collaborative detection, only some nodes conduct spectrum perception, while the other part remains dormant. The proportion of nodes entering dormant state is called dormancy rate, which is represented by α (0≤ α ≤1). In addition, in order to minimize energy consumption, a screening strategy is implemented for the nodes sending decision data to the fusion center, with the screening thresholds of theta 1 and theta 2 and the screening domain of θ1<Ei<θ2. When the detected energy is within the screening domain, the node will not send decision data to the fusion center to filter out unsatisfactory detection results and reduce unnecessary data transmission. The screening rate is β (0≤ β ≤1).

For all collaboration nodes, pd is set as the local detection rate, and the global detection rate of the free spectrum can be calculated as follows:

\[ R_D = 1 - \left[ 1 - \alpha \right] \left[ 1 - \beta \right] p_d \]  

Where, the relation between screening rate β and screening threshold is expressed as follows:

\[ \beta = \frac{\Pi(T_\theta \theta_1/2)}{\Pi(T_\theta \theta_2/2)} \]  

Ideally, the global detection rate should be maximized. However, it can be seen from formulae (1) and (2) that if the energy consumption is low, the greater the α and β the better, but the lower the detection rate. On the contrary, the smaller the alpha and beta, the higher the detection rate but the higher the energy consumption. It can be seen that they restrict each other and need multi-objective optimization.

4. Development characteristics of photovoltaic power generation

The application market of photovoltaic power generation has been developing for more than ten years in China, and the cumulative capacity of photovoltaic power generation maintains a good development momentum in 2018. By the end of 2018, the cumulative installed capacity of solar photovoltaic power generation in China has reached 174 million kilowatts, an increase of 34% compared with the same period last year, accounting for more than 9% of the total installed power supply. Among them, 123.84 million kilowatts are centralized photovoltaic power plants and 5.62 million kilowatts are distributed photovoltaic power plants, as shown in Figure 1.

![Figure 1. Photovoltaic development from 2010 to 2018 in China](image)
In 2018, China installed 44.26 million kilowatts of solar photovoltaic power. Despite the decline, solar photovoltaic power continued to lead the growth of new installed power sources. For the second year in a row, solar power surpassed coal power to rank first among all new installed power sources, accounting for 36% of the total installed capacity of the year. The installed capacity of centralized power stations increased by 23.3 million kw, and the installed capacity of distributed photovoltaic power stations increased by 20.96 million kw.

But there will also be problems with the growth of photovoltaic capacity. First, with the decreasing cost of photovoltaic modules, inverters and related construction, the large-scale photovoltaic access will impact the unstable output of the power system. Secondly, accurate prediction of distributed photovoltaic output has not achieved low cost and high accuracy at present. Third, in the 25-year operation period, there are some problems need to be solved such as how to ensure the good operation and maintenance of distributed photovoltaic, especially in remote areas such as some photovoltaic poverty alleviation projects, and how to enhance the adaptive processing of photovoltaic power generation data collection and transmission signal and channel balance ability.

5. Key technologies of photovoltaic cloud network
At the present stage, the construction of "ubiquitous power Internet of things" focuses on the endings of all links of the system "source-network-load-storage", supporting data acquisition and specific business development. It can provide sufficient and effective information and supporting data for the planning and construction, operation, management, integrated services, new business model, enterprise ecological environment construction, etc. through the wide application of big data, cloud computing, Internet of things, mobile communications, artificial intelligence, chain blocks, edge information technology and intelligent technology and pooling resources.

State Grid’s distributed photovoltaic cloud network fully applies mobile communications, artificial intelligence and other modern information and communication technology, implements interconnection of each link of power system and human-computer interaction, and has the function of comprehensive information awareness, efficient processing, and flexible application. It provides strong support data resources for the safe and economic operation of power grid, improvement of business performance and service quality, and development of strategic emerging industries. The strong smart grid carrying power flow and the ubiquitous power Internet of things carrying data flow complement and integrate with each other to form a powerful value creation platform and jointly constitute the "three-in-one" energy Internet of things carrying energy flow, business flow and data flow.

The design architecture focuses on the photovoltaic industry chain and ecosystem, and provides comprehensive intelligent service which can solve pain points such as shallow industry data mining, poor coordination mechanism, information asymmetry. It can serve government, power grid enterprise, photovoltaic devices and photovoltaic investment enterprise, and launch innovation projects trading and photovoltaic museum to upgrade the industry. Based on the previous system, focusing on internal and external system interconnection, data sharing, and business communication, to build a typical architecture of ubiquitous power Internet of things which can provide "three basic services and five value-added services", integrate resources from government departments, industry associations, power grid companies, manufacturers, power station owners, construction units, operational enterprises and financial institutions, and to build a "industry-university-institute" multiple linkage of distributed photovoltaic service ecosystem. In line with the idea of platform and ecology, focusing on building a comprehensive intelligent energy service system, we unify the external business portals and entrances to achieve drainage and enabling, innovate and promote the collaborative service of source network load and storage, actively build the energy Internet ecosystem, promote the emerging business to realize "all flowers are in bloom", and drive the upstream and downstream of the industrial chain to develop together.
6. Prospect of photovoltaic power

6.1. Grid parity helps to realize national photovoltaic

The year 2019 marks the new century of grid parity to photovoltaic power in China. The National Energy Administration has officially announced the photovoltaic grid parity demonstration project, laying an important foundation for the national photovoltaic, energy production and consumption revolution. Distributed photovoltaic will replace the large centralized photovoltaic power station on the ground, become the main force of Chinese photovoltaic power generation. Rural households will also implement photovoltaic. The whole society will realize national photovoltaic through the direct purchase of green electricity, photovoltaic equipment and assets. Technology innovation brings breakthrough of solar thermal conversion improvement, and power generation efficiency will be greatly improved.

6.2. Photovoltaic will form an intelligent system of things

Based on the current photovoltaic cloud network, considering key technology breakthroughs at the sensing layer, network layer and platform layer, coordinating the construction tasks related to photovoltaic information sensing, to create an industry-level intelligent system of things jointly. The emphasis is to unify the terminal function design, access standard and interaction specification, and design the unified information model for equipment level distribution for sensing and supporting edge aggregation computing. The R&D and deployment of intelligent terminals should fully consider the needs of other specialties, realize the cross-specialty reuse of the allocated electric side acquisition device, communication resources, edge computing and data resources, and promote the co-construction and sharing of all specialties. The develop and deploy management center of Internet of things promotes standardized access to various photovoltaic terminals and unified management of Internet of things. New technologies such as artificial intelligence and edge computing will be applied to realize national photovoltaic autonomy, cloud-edge collaboration and capacity opening. The overall framework of the photovoltaic power generation remote monitoring data acquisition system based on the Internet of things is shown in figure 2.

![Overall framework of photovoltaic power generation remote monitoring data acquisition system](image)

Figure 2. Overall framework of photovoltaic power generation remote monitoring data acquisition system
6.3. Intelligent photovoltaic Internet of things system

Adhere to the combination of top-level design and grassroots initiative. For one thing, preliminary plan the emerging business through the top-level design, for another, accumulate new forms of business and new models through grassroots initiatives. The key is to establish "horizontal synergy, vertical penetration" and "all link, full penetration, full coverage, whole ecosystem, whole scene" photovoltaic management system. Based on the photovoltaic power generation remote monitoring and data acquisition system, to complete photovoltaic process data sharing accommodation, fully realize photovoltaic process management informationization, complete implementation and application of photovoltaic module deployment.

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