The Substation Internet of Things System based on Edge Computing

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Abstract. In response to the demand of the development of energy Internet for the comprehensive perception and wide interconnection of massive data of power system, the concept of ubiquitous power Internet of things (UPIoT), which comes from the deep integration of Internet of things technology and smart grid, has been put forward, becoming an important content and key link in the transformation and upgrading of power grid enterprises. The centralized computing mode previously adopted by smart grid can no longer meet the needs of large-scale computing and rapid response, so the ubiquitous power Internet of things should adopt the operation mode combining centralized computing and distributed computing. Firstly, this paper discusses the basic concepts and main characteristics of ubiquitous power Internet of things. Based on edge computing, this paper constructs the basic architecture of substation internet of things composed of perception layer, network layer, platform layer and application layer. Secondly, it discusses the key technologies in the construction of substation internet of things, and finally analyzes the specific application of edge computing in the construction of substation internet of things.

1. Introduction
Promoting the energy revolution and the development of green, low-carbon and clean energy system is an important breakthrough point for China's energy development in the new era. In the future, the energy industry will gradually integrate with big data, virtual power plants, smart grid, Internet of things, sharing economy, blockchain technology and digital technology. The cost of power generation will continue to fall, the focus of energy investment will shift to green and clean energy, and the industrial structure and energy consumption structure will be further optimized. China has drawn up a development roadmap for renewable energy, advanced energy storage, smart grid and other technologies in the “energy technology revolution and innovation plan (2016-2030)”, and technological innovation has become an important strategic support for future energy transformation.

In the context of energy transformation, in 2019, state grid corporation of China proposed the goal of accelerating the construction of UPIoT (ubiquitous power Internet of things), and positioned the UPIoT as an important part of the energy Internet. In essence, UPIoT is a kind of Internet of things, which is a specific manifestation and application of the ubiquitous Internet of things in the power industry. At present, a series of researches have been carried out on the application of Internet of things in power system at home and abroad. Reference [1] elaborates the compatibility between the Internet of things and smart grid from the aspects of connotation, characteristics and implementation means. Reference [2] and [3] put forward the basic concept of power Internet of things, and
constructed the layered architecture of power Internet of things covering four links of power transmission, power transformation, power distribution and electricity consumption. Reference [4]-[10] studies the application of Internet of things technology in substation operation and maintenance, distribution network operation, intelligent electricity consumption, asset management and other fields, and sorts out the key technologies supporting the construction of power Internet of things. Reference [11] further puts forward the concept of intelligent energy Internet of things, and looks forward to the application prospect of Internet of things technology in energy Internet. To sum up, it can be seen that domestic and foreign existing research focuses on the application architecture of Internet of things technology in the whole energy and power industry, and information interconnection is the basis for the construction of UPIoT [12]. At present, the information interconnection has not been fully realized with the massive equipment on the power side, and the "last kilometer" challenge of the power system still exists and needs to be solved urgently. Therefore, in the future UPIoT will focus on the distribution of electricity side, which is also the focus of this paper.

Firstly, this paper discusses the basic concepts and main characteristics of UPIoT. Based on edge computing, this paper constructs the basic architecture of substation internet of things composed of perception layer, network layer, platform layer and application layer. Secondly, it discusses the key technologies in the construction of substation internet of things, and finally analyzes the specific application of edge computing in the construction of substation internet of things.

2. The basic concept and main characteristic of UPIoT

2.1. The basic concept
Ubiquitous linkage refers to the information connection and interaction between any time, any place, any person and any thing. UPIoT is the specific manifestation and application of ubiquitous Internet of things in the power industry. In other words, UPIoT is a special kind of Internet of things, which is an information network connecting power users and their equipment, power generation enterprises and their equipment, suppliers and their equipment, as well as people and things.

Smart grid is an information physical system, and UPIoT is the upgrade and expansion of its information system. UPIoT expands the data source of Internet of things from the grid side to the power generation side and the power consumption side through extensive arrangement of end-sensing nodes. And the external environment data, such as temperature and humidity, and market quotation, settlement price and other transaction data are included in the data collected. By obtaining and sharing the whole link and multi-type data of power production, transmission and utilization, the comprehensive perception of the whole intelligent power ecosystem is realized [13].

2.2. The main characteristic
The UPIoT penetrates and deeply integrates the new communication technology and the new generation power system. In the perception layer, it is the perception ability of the Internet of everything. in the network layer, it is the ubiquitous and ubiquitous communication ability, in the platform layer, it is the control ability of panoramic equipment and data. Its main characteristic basically has 4 respects [14].

2.2.1. Overall perception. Overall perception refers to the dynamic acquisition of the state information of different devices and users in each link of "generation-transmission-substation-consumption" through RFID and sensors.

2.2.2. Ubiquitous connections. Ubiquitous connection refers to the real-time connection of all devices and users' information and data in the power system through the power private network or mobile network, so as to realize the real-time ubiquitous connection between the power grid and upstream and downstream enterprises and customers.
2.2.3. **Open sharing.** Open sharing refers to the sharing and management of data using intelligent technologies on a unified platform. And improve data quality, mining effective information, achieve data up and down link, omni-directional real-time interaction. It will better play a leading role, create greater opportunities for the development of the whole industry and more market players, and realize value co-creation.

2.2.4. **Integrated innovation.** Integrated innovation means to realize the whole business online and the safe and stable operation of the power grid through different equipment, users and spatio-temporal information.

3. **The basic architecture of substation internet of things based on edge computing**

The construction of UPIoT should be combined with the construction of first-class distribution network. However, at present, the information interconnection of massive equipment on the distribution side has not been completely realized, and the "last kilometer" challenge of the power system still exists and needs to be solved urgently. As an important equipment of distribution system, substation Internet of things construction is an important guarantee to improve the operation safety of distribution system.

Substation Internet of things architecture consists of four layers: perception layer, network layer, platform layer and application layer, as shown in Figure 1.
3.1. The Perception Layer
On the sensing extension layer, intelligent sensor elements and devices are used to realize the complete collection of information and the comprehensive perception of substation status. Using LoRa, Zigbee, NB-IoT, wired network and local wireless network communication methods upload to the edge computing layer of Hub Nets, realize local edge computing and terminal intelligence. At the same time, the automatic response of the terminal is realized according to the calculation results of the upper system and the control command. The extended sensing layer and the edge computing layer can realize the comprehensive sensing of substations.

3.2. The Network Layer
The network layer realizes data transmission and real-time communication between the edge computing layer and platform layer. At present, the network transmission modes of power system are mainly GPRS, 4G wireless public network communication, power carrier communication and optical fiber communication. The maturity of 5G communication will inevitably make it play an important role in the future construction of UPIoT. In addition, the development of LTE wireless private network, beidou satellite communication, wide-area narrowband Internet of things and other communication modes has also increased the flexibility and fault tolerance of communication, and greatly enhanced the network transmission capacity.

3.3. The Platform Layer
The platform layer makes use of big data, artificial intelligence and cloud computing to realize data management and sharing, improve data quality, mine effective information, realize up-down connection and all-round interaction of data, and use the management center of Internet of things and data center to improve transformer data efficient processing and cloud-fog-edge collaboration.

3.4. The Application Layer
On the basis of the platform layer, the application layer realizes the application of intelligent operation and maintenance, network capacity and load prediction, equipment online monitoring, power asset management and power consumption analysis, and promotes the safe and stable operation of the distribution network.

4. The Key Technologies of Substation Internet of Things Construction
The construction of substation internet of things involves many key technologies. For substation internet of things architecture of four layers structure contains four elements, namely the terminal information comprehensive perception and the unity of the intelligent terminals, data transfer, data analysis and management, and information comprehensive application, involves the key technologies of intelligent sensor technology, edge computing technology, modern communication technology, big data and cloud computing, etc.

4.1. Intelligent Sensor Technology
At present, most substation on-site acquisition equipment coverage is insufficient, unified management of things is not realized, communication access network depth is insufficient, bandwidth is insufficient, data reliability is poor, accuracy is low. Therefore, it is necessary to rely on intelligent sensors and devices with high accuracy, low power consumption and miniaturization to promote same-source data collection, so as to achieve deep coverage of substation monitoring and real-time interaction of multi-parameter data, and improve the intelligence of terminals and edge computing level.

4.2. Edge Computing Technology
The centralized computing mode previously adopted by smart grid can no longer meet the needs of large-scale computing and rapid response, so the UPIoT should adopt the operation mode combining
centralized computing and distributed computing. Edge computing is mainly responsible for real-time and short-period data processing tasks as well as real-time processing and execution of local businesses, providing high-value data for the cloud. Cloud computing is responsible for computing tasks that edge nodes are not competent for. Meanwhile, through big data analysis, it is responsible for processing non-real-time and long-period data.

Edge computing technology is applied to the substation Internet of things system to develop Hub Nets of transformer distribution, which can realize data collection and local processing of local monitoring system of substation, complete data statistics, real-time control, state diagnosis and other functions, and improve the intelligent level of the terminal. To solve the existing problems of edge computing, such as limited storage resources and difficulty of artificial intelligence in edge parallelism, 5G communication, cloud-edge collaboration, model segmentation and model tailoring can be studied.

4.3. Modern communication technology
The transmission of massive data requires the power grid to have an integrated communication network. The development of modern communication technology has improved the communication capacity of the existing power grid. Power beidou technology, power wireless private network, 5G and low-power wide area network (LPWAN) and other modern communication technologies are the main means of network communication of substations internet of things.

4.4. Internet of things platform technology
The cloud platform of substation Internet of things is the computing power support platform, data fusion platform and application development platform of substation Internet of things. On the basis of using cloud computing, big data, artificial intelligence and other advanced technologies to integrate, analyze and manage the massive perceptual data of substations, build relevant business application platforms according to business needs, such as intelligent operation and maintenance platform, network capacity and load prediction platform, electricity analysis, power asset management platform, etc. to support the implementation of relevant businesses.

5. Edge computing enables the substation internet of things

5.1. The concept of edge computing
Edge computing refers to an open platform integrating network, computing, storage and application of core capabilities on the side close to the object or data source to provide nearest terminal services. Its applications are launched at the edge to generate faster network service response, meeting the industry's basic needs in real-time business, application intelligence, security and privacy protection.

5.2. Edge computing and substation internet of things
The whole system is divided into three layers: cloud, edge and field. Edge computing is located between the cloud and the field layer. The edge layer supports the access of various field devices downward and docking with the cloud upward. Figure 2 is the logical view.

![Figure 2. Edge computing logical view for substation internet of things](image)
5.2.1. The field layer. The field layer connects field nodes such as sensors, actuators, devices, control systems, and assets. These field nodes connect with the edge gateway and other devices in the edge layer through various kinds of field networks and industrial buses to realize the connection of data flow and control flow between the field layer and the edge layer.

5.2.2. The edge layer. The edge layer is the core of edge computing three-layer architecture. It receives, processes and forwards data flows from the field layer, providing such time-sensitive services as intellisense, security and privacy protection, data analysis, intelligent computing, process optimization and real-time control. The edge layer encapsulates computing, storage and network resources on the edge side. The edge layer also includes edge manager software, which mainly provides business choreography or direct invocation capabilities to manipulate edge computing nodes to complete tasks.

5.2.3. The cloud computing layer. The cloud computing layer receives data flow from the edge layer, and optimizes the resource scheduling and field production process from the global scope to the edge layer and through the edge layer to the field information.

6. Conclusion
Under the background that state grid corporation of China strongly advocates the development of UPIoT, this paper explains the basic concept and main characteristics of UPIoT. This paper constructs the substation internet of things based on edge computing, and analyzes the key technologies, discusses the specific application and architecture of edge computing in substation internet of things. It is hoped that this paper can provide reference for the research of ubiquitous power Internet of things researchers.

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