Research on Construction and Application of Power Distribution Internet of Things

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Abstract. As an important part of power grid aggregation and distribution, the distribution network is becoming more and more important and intelligent with the development of the Internet of Things technology. As a high-priority system for power supply services, the distribution network faces customers directly, so it also faces greater challenges. On this basis, based on the traditional distribution network, this paper studies and comparatively analyzes the advantages of the new distribution Internet of Things model, proposes a four-tier architecture system for the construction of distribution Internet of Things. Furthermore, the application and development process of the Internet of Things technology in the distribution network is explained from the three key technologies of comprehensive perception technology, diverse communications, and edge computing. Finally, from the perspective of operation and maintenance management and fault diagnosis and early warning, the application prospects of the Internet of things for power distribution are discussed.

1. Introduction

With the rapid development of the contemporary Internet industry, the market for information technology such as the Internet of Things(IoT), cloud computing, big data, artificial intelligence has been widely explored, and gradually applied to many areas of traditional industries, becoming a powerful driving force for technological innovation and industrial change[1]. As an important basic branch of the traditional industry, the transformation and development direction of the power grid will also become a hot spot of current exploration. The power grid is a key link for the collective transmission and conversion of energy. On the one hand, the depletion of fossil raw materials and global warming are gradually intensified. As well as the strict requirements of the digital and information society on the smart grid, automation development, and power quality reliability[2], it has made the traditional grid industry change faster.

Distribution network (voltage level of 10 kV and below) is an important link in the operation of the power grid. As the highest priority system for power supply services, the distribution network directly contacts customers and faces the challenges of rapid changes in management needs, large scale of management equipment, and high service requirements. At the same time, the voltage level of the distribution network is generally low, its development and construction cycle is short, and the scope of influence of a single device is small, so it is very suitable for the pilot and rapid promotion of new technologies and new equipment. It is an indispensable infrastructure for urban and rural development and intelligent grid evolution. Therefore, the distribution network is the most important part of the rapid development of the ubiquitous electric power Internet of Things.

The distribution network integrates the latest generation of information and communication technology represented by the Internet industry to form a new development form, namely the Internet
of things for distribution, to improve the level of distribution network construction, operation and maintenance, and to adapt to lean and efficient management requirements, quickly and flexibly adapt to changes in the business needs of users, and meet the requirements of the new development of the energy industry on the transformation and development of the distribution network\[3\], it will be a positive response to the integration and development trend of the energy revolution and the digital revolution.

Based on the characteristics of device interconnection, comprehensive perception, intelligent decision-making, and operation and maintenance management, this article will further analyze the distribution IoT and traditional distribution networks, and put forward its architecture based on the overall idea of distribution IoT construction, finally analyze the possible application effects and development prospects of the electrical distribution IoT.

2. Comparison of Traditional Distribution Network and Distribution Internet of Things

The digital information technology with IoT technology as the core in the IoT of distribution is the centralized embodiment of the intelligence of the IoT of distribution. The extension of the flexible distribution network construction structure is the basis for the future transformation and development of the IoT of distribution.

The IoT of distribution aims to solve the professional pain points such as the perceived depth, communication range, data quality, distribution network operation and maintenance, and user service in the traditional distribution network field. It is based on the principles of small scope, multiple types, low cost, and high effectiveness. Completed the application of extensive interconnection of power grids, equipment panoramic perception, intelligent and efficient operation, and accurate and transparent management functions, achieving panoramic data management, transparent operation status, intelligent diagnosis and decision-making, and rapid service response, promoting the transformation of the distribution network from the traditional operation inspection mode to the intelligent operation mode.

Compared with the traditional power distribution network and the power distribution IoT, as shown in Figure 1 below, the characteristics of the power distribution IoT industry can be summarized as follows:

![Figure 1. Comparison of traditional distribution network and distribution IoT](image_url)

1) Terminal equipment is widely interconnected. Complete the comprehensive interaction of power distribution area network equipment, and build a healthy, stable, and reliable operating model for business integration within and outside the business.

2) Comprehensive perception of operating status. Realize all-round monitoring and identification of the data collection, transmission and distribution process of power grid equipment, and complete holographic perception of various structured and unstructured data in different application scenarios.

3) Fast and intelligent diagnostic decisions. Combining advanced technologies such as artificial intelligence, edge computing, and big data, it can realize the functions of storage, mining, rapid
processing, and autonomous analysis of massive data, and then it can complete power distribution business functions such as application services and information presentation.

4) Operation and maintenance management is convenient and efficient. The traditional power industry control system is deeply integrated with the Internet of Things IP-based communication technology, and based on the unified information model, plug-and-play maintenance-free mass distribution terminal equipment is implemented [4].

3. The overall architecture of the power distribution IoT construction

The overall architecture of the ubiquitous power IoT construction of power distribution equipment is shown in Figure 2 below.

![Figure 2. The overall construction architecture of the distribution Internet of Things](image)

The architecture includes four layers: an application layer, a platform layer, a network layer, and a perception layer. The perception layer relies on advanced sensor technology to complete all-round and multi-angle intelligent acquisition, monitoring, and processing of power distribution equipment status. At the same time, the introduction of edge technology solves the problem of on-site processing of regional computing tasks, while also reducing Platform and application layer server data processing costs. Connect the sensing layer and the platform layer through network channels based on various communication methods, and realize the mutual reception, transmission and scheduling of data between them. Among them, 5G technology and power carrier communication methods will become the main direction for the future development of the network layer. The platform layer uses artificial intelligence technology to efficiently and accurately process all types of data transmitted by the perception layer, which is the basis of the advanced application layer. The application layer completes the integration of the production and operation of the power grid company, the management of the business model, and other emerging services through a high degree of integration of data in various dimensions. The online operation and maintenance of various businesses has accelerated the iterative updating of the business model[5]. The commercial available value of the traditional distribution network industry increased. The above four layers of structures complement each other to jointly realize the entire process of inspection and maintenance of power equipment by the Internet of things for distribution.
4. Application Exploration of Distribution Internet of Things

The distribution IoT follows the four-layer overall architecture of “applications-platforms-networks-terminals”, and has been pilot-tested in Shandong, Jiangsu, Zhejiang and other places. Because the distribution Internet of Things has brought essential changes in comprehensive perception, equipment interconnection, rapid decision-making, and operation modes, it has promoted the distribution network to bring significant results in two aspects: technological development, equipment operation and maintenance management, and state analysis and early warning.

4.1 Technological development

The construction of the digital project of the power distribution Internet of Things will also drive the development of a number of key technologies, mainly advanced device sensing technology, autonomous inspection methods, diversified communication technologies and intelligent digital processing and analysis technologies. As shown in Figure 3.

Figure 3. Key technologies for the construction of power distribution IoT

4.1.1 Intelligent perception technology.

Sensor technology is the core issue of intelligent sensing and automation of power equipment status information in the power distribution IoT. In the 21st century under the background of industrialization and digitalization, traditional sensors have not satisfied the trend of smart grid development, and more new sensors with autonomous data processing have developed into the mainstream. Compared with traditional sensors, the new sensors have high accuracy, strong robustness and better adaptive capabilities.

The new sensor is widely used in wireless sensor networks. It uses a large number of micro sensor nodes with micro processing capabilities to carry out device data collection, aggregation, and processing of potential target values within the network coverage[6]. Wireless sensor networks have the advantages of a long life cycle, good data fusion performance, and strong robustness, which can provide higher interaction, interconnection, and mutual inductance for the power distribution Internet of Things. Nevertheless, wireless sensor networks need to be replenished at all times during the work process. If combined with miniaturized design, wireless sensor networks will have a wider prospect.

In terms of inspection methods, the inspection platform has gradually adopted integrated sensor equipment. Inspection robots and drones have become popular inspection methods to assist or replace manual inspections. Various types of image acquisition sensors configured by themselves mainly include visible light cameras, infrared cameras, and ultraviolet imagers, but at this stage, there is a problem that the data monitoring terminal fails to implement local processing and analysis, which
results in a long and inefficient failure diagnosis process. For this reason, the introduction of chips based on artificial intelligence technology can process the structured or unstructured data of the field environment or power equipment collected by the terminal in real time. At the same time, Beidou positioning and navigation technology will also become an important development direction for distribution network robots and drone inspection platforms.

4.1.2 Communication technology.
Due to the differences in the location of the traditional Internet of Things, the application of communication technologies is also different. In the local area network communication environment that is close to each other, wireless communication technologies such as WIFI and Bluetooth have been widely adopted because of their easy operation, low cost, and fast speed. Conversely, long-distance communication considers how to ensure the real-time and accuracy of transmission. Based on this, mobile cellular network technologies such as 3G and 4G are mostly selected. In addition, the existing network communication technology at the current stage also has disadvantages such as high power consumption and insufficient anti-interference ability. Therefore, the main improvement directions of future communication technologies are transmission accuracy, long distance, anti-interference and low cost. At present, the communication technologies with good development prospects are: broadband carrier, 5G, Low-Power Wide-Area Network (LPWAN).

4.1.3 Edge computing technology.
In order to solve the problem of effective collection and fast processing of a large amount of structured and unstructured data, State Grid Corporation in the "White Paper on the Development of Distribution IoT Technology" proposed the use of "unified hardware platform + edge operating system + APP business application software" in the marginal area Strategy[7], applying core technologies such as big data, cloud computing, internet of things, artificial intelligence, storage. Adopting edge computing methods, many controls will be implemented through local devices without having to be handed over to the cloud master. This will undoubtedly greatly improve the processing efficiency and reduce the pressure of cloud master communication and calculation. Until now, the research direction of edge computing has focused on mobile edge networks, edge clouds, et. Mobile edge computing will be an important branch of future research and development.

4.2 Operations Management
The construction of the power distribution Internet of Things aims to develop the data of the power distribution network into a value-added resource. The efficient use of the data of the transformer equipment ensures the health and reliability of the power grid operation, thereby reducing the cost of operation and maintenance of the power distribution network. The operation and maintenance costs of distribution network data have full chain expenditures such as full perception, fast transmission, real-time processing, intelligent analysis, and security maintenance. In the distribution Internet of Things, the economic data is redefined to achieve accurate management of the enterprise, and then use the development of economic markets to drive further improvement and optimization of the industry. At the same time, the inspection methods of power equipment for power distribution Internet of Things are becoming more intelligent and platform-based. Inspection robots and drones with multi-functional sensors have also begun to assist or replace the manual implementation of full information perception of equipment status. The manual inspection posts will be replaced by advanced technology, thereby realizing the automation and unmanned operation of the operation and maintenance management of power distribution equipment.

4.3 Fault diagnosis and early warning application of distribution network
Power equipment fault diagnosis and early warning based on multi-information fusion is an important technology to improve the reliability of regional power supply, discover the gradual change of
equipment status, and excavate the limits of equipment operation. It is also the research direction of the construction flooding to realize the holographic perception of the device status in the power IoT.

The power distribution Internet of Things combines the four-layer architecture system of "applications-platforms-networks-terminals" to play the local processing and timely execution functions of edge computing technology, and then quickly locate the fault location and formulate further regional maintenance plans. At the same time, combined with the distribution network topology and environmental data, through analysis of equipment failures and power outages, combined with artificial intelligence technology, issued emergency repair plan strategies, transforming passive maintenance into active repairs, improving the timeliness of failure repairs and the quality of customer service[8]. Finally, according to the historical status values and current data status perception information during the operation of the distribution network, classify the abnormal results, set the fault risk factor, and build an integrated management and fault early warning system for the distribution network. Corresponding fault conditions generate different maintenance plans and carry out active maintenance work in a targeted manner.

5. SUMMARY
The distribution IoT construction follows the four-layer architecture of “application-platform-network-terminal” system, combined with advanced information technology as the mainstream of intelligent sensing, communication, and data processing technologies, which reflects the characteristics of the hub, platform, interaction, and automation, and is also an important means for the future development of smart grids. Nowadays, the IoT of power distribution has penetrated into various traditional power fields and emerging industries, and is in the process of continuous application and improvement. It has also promoted the update of distribution network equipment operation and maintenance management and status analysis and early warning technologies, effectively improves the management level of distribution network operation and maintenance, realizes the real-time and efficient transmission of various status data of distribution network to equipment centralized control center, thereby improving the automation and intelligence of the distribution network, and promoting the progress and development of the power industry.

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