Research on the Topology of the Ubiquitous IoT Distribution Network in Power System

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Abstract. Starting from the perception layer, network layer, platform layer and application layer, the construction of ubiquitous IoTIPS (Internet of Things in Power System) integrates and applies new technologies such as sensor technology, power electronics technology, automatic control, cloud computing, intelligent terminal and so on, which is the core task to implement the strategic goal of “three types, two networks and the first class in the world-class” of the State Grid Corporation. Based on the construction objective of ubiquitous IoTIPS, this paper focuses on the application scenario of distribution network and analyses its network topology. Combined with the Smart Energy Router (SER) proposed in the context of energy Internet, the topology of a new ubiquitous IoT distribution network in power system is proposed. Aiming at the massive data brought by the Internet of Things, a user data information network independent of the communication network used to transmit control or measure signals in the existing distribution network is proposed. Finally, the key technologies are briefly sorted out layer by layer, and the application prospect of the topology of the proposed ubiquitous IoT distribution network in power system is prospected.

1. The Concept and Framework of Ubiquitous IOTIPS

The ubiquitous IoT refers to the information interconnection and interaction between everyone and everything at any time and anywhere. However, the ubiquitous IOTIPS refers to the information interconnection and interaction between power users and their equipment, power grid enterprises and their equipment, power generation enterprises and their equipment, suppliers and their equipment, as well as people and things.

From the perspective of technology, the basic architecture of ubiquitous IOTIPS includes four layers: the perception layer, the network layer, the platform layer and the application layer. The perception layer realizes real-time data acquisition of power transmission and transformation system at all levels and power users. The network layer achieves the organic integration of energy network and information network. The platform layer achieves the centralized management and integrated analysis of data to achieve the goal of standard and interface unification. The application layer achieves various power “transmission and transformation” services on the basis of big data analysis.
2. The Existing Smart Distribution Network Topology

2.1 The Traditional Smart Distribution Network

Fig. 1 shows the micro-grid topology that initially realizes the intelligent power grid. It can be seen that the application of a large number of power electronic devices greatly improves the degree of freedom of capacity flow in the micro grid. Various controllable power electronic converters provide solutions for grid integration of new energy and power quality improvement. However, based on the micro grid in this topology, the main function of information channel is to transmit measurement, measure signals and send control commands, and its topology is point-to-point or radial. In addition, due to regional load forms, new energy types and other differentiated factors, AC and DC buses tend to be relatively independent.

2.2 The Smart Distribution Network Based on Energy Router

Fig 2. shows the narrow energy Internet topology based on “energy router”, “distributed energy” and “intelligent control strategies” proposed by some universities and research institutes at home and abroad around 2010, which can also be understood as the energy Internet at the micro-grid level. Among them, the SER can make AC and DC buses coexist in the micro-grid. All power sources, energy storage and loads can be connected to DC buses. The bottleneck of this kind of topology is that if the SER link fails, the whole micro-grid will face the risk of complete paralysis. Adding redundant power electronic converters to the AC bus side can improve the reliability of the network, but also increase the investment. Based on this topology, the lateral interconnection between converters and the connection between different control levels are added to the original radial information flow. However, it should be noted that due to the limitation of connection bandwidth, not all data form a closed loop.

Figure 1. The distribution network topology using power electronic devices

Figure 2. The distribution network topology using the energy router

3. The Topology of Ubiquitous IoT Distribution Network in Power System

3.1 Research Background of Ubiquitous IoT Distribution Network in Power System

3.1.1 Objective Requirements for Power Grid Development to Penetrate to User Side

As the front end of the perception of user data, smart distribution network plays an irreplaceable role in user data acquisition. At present, the State Grid Corporation has the largest scale of power grid in the world, establishes a huge power grid operation system, connects 540 million terminals such as smart watt-hour meters, and collects more than 60TB of data per day. There are more than 280,000 charging piles connected to the vehicle networking, and 225 million registered users on e-commerce platforms. On the one hand, this is the solid foundation for the construction of the ubiquitous IOTIPS by the State Grid Corporation. On the other hand, such a huge amount of data can not be transmitted and stored only by relying on the existing communication network in the power grid. Meanwhile, as more types of power sources are responsible for access to the power grid, the problems of inadequate...
information penetration and insufficient traceability caused by various data formats and structures are increasingly obvious. With the deepening of power grid informatization and the increasing dependence of modern enterprises on digitalization, there is an urgent need to integrate the Internet of Things technology into the construction of power grid, especially in the process of distribution network construction, so as to improve the response speed to user needs.

3.1.2 Internet Thinking Provides a New Way of Thinking for the Existing Power Grid Management Model

Drawing on the thinking of some Internet companies, the enterprise’s “middle office” can be constructed to deal with the management problems brought by the new business. Before the emergence of the concept of the “middle office”, in the information model, the front end is the application end supporting business, and the back end is the application system providing services for the front end. However, with the changeability of market, user demand and business, the rigid application at the bottom can not provide timely support. Enterprises need a strong middle layer to provide support for high-frequency and changeable business and to provide multi-end access channels for different audiences. The information construction mode based on “big middle office and small front office” comes into vogue.

The enterprise middle offices can be divided into the basic middle office, technology middle office, data middle office and business middle office from the part near the background to the foreground. The basic middle office is also known as the PaaS (Platform as a Service) container. The keywords are container cluster management and agile development. The technology middle office, data middle office and business middle office can be regarded as links to connect underlying services and perceive upper information. Relevant literature points out that the concept of middle office is more suitable for leading enterprises with many subsidiaries and a wide range of business.

3.1.3 The Rapid Development of Sensors, Smart Mobile Terminals and Other Technologies Provides Conditions for the Landing of IOTIPS

In recent years, the new technologies of power grid such as sensors, intelligent terminals, data mining algorithms, and power electronic equipment have made great progress. These technologies provide conditions for the information acquisition of smart distribution network, data fast processing and the landing of flexible control strategies based on user needs. Enterprise data centers, which are gradually online, also provide a physical basis for the application of information.

3.2 Power Network Topology for Ubiquitous IOTIPS

Fig.3 is the topology of IOTIPS which introduces the concept of ubiquitous interconnection. Its energy network topology is consistent with Fig.2, but the information network penetrates into user data. If we say that the smart grid and global energy Internet greatly enhance the intelligence level of the power grid, the construction of ubiquitous IOTIPS will focus on the data network of “users”, and form an organic interconnection with the power grid. As shown in Fig.3, all kinds of power supply, energy storage and load objects are generating operation data at all times, and their accumulation will make the amount of data in the network increase exponentially. The object of information transmission in ubiquitous IOTIPS is no longer the electrical quantity information and control instructions of the power grid as mentioned above. Meanwhile, it is necessary to build an independent user power consumption information network. On the one hand, the requirement for independence is that the transmission frequency and reliability of data such as original control instructions are far greater than user information, and the independent network construction can reduce the cost compared with expanding the original network bandwidth. On the other hand, the bandwidth of the original network will be far from enough to meet the data quantity requirements of user data. At the same time, the superior information network of the micro-grid will be interconnected with the newly built data center and will establish links with other forms of energy information network. The data center and user data network will provide software and hardware basis for the optimization of energy finance, energy services, energy trading and energy networks. In such a network topology, the unification of various data structures and data interfaces, and traceability arbitration in the use of multi-source data will become key technologies. In 2017, the State Grid Corporation put forward the requirement of
comprehensive application of three-dimensional design, whose significance is to realize “data connection” and build “digital state grid” so as to achieve the integration goal of “one source of data, one grid map and one line of business”. Taking the three-dimensional design results as the data carrier of information network is the key link to sort out and unify all aspects of data.

Figure 3. The topology of the ubiquitous IoT distribution network in power system proposed in this paper

In the perception layer, a variety of sensors and existing storage units run through the whole life cycle of power grid assets discretely. It is innovatively proposed to classify and discuss the data according to the life cycle of the data that is to divide the data into “solid data and dynamic data”. Obviously, the infrastructure information of power grid assets, such as design data and construction data, are all solid-state data. The characteristics of such data are that it will not change for a long time after one-time input. The control data of the power grid and the data collected by SCADA in real time are all dynamic data, which need to be updated in real time. The system is also often required to respond in a timely manner. In addition, the user data and data from other networks in the micro grid are also updated dynamically due to the adoption of “incremental update” in the micro grid. However, the updating real-time requirement of such data is not as high as the control signal and other dynamic engineering data, which can be updated regularly.

In storage layer, the solid-state data is stored on edge servers in the form of local area network(LAN) cloud. When transmission is needed, the system dynamically allocates bandwidth. For engineering dynamic data requiring fast response, it is necessary to reserve space for updating in storage space at all times, and set up dedicated transmission lines to ensure its real-time performance. When the dynamic data is responded, it will be moved into the backup area, which is stored in the cloud. According to the data type, the backup area will be cleaned up and updated regularly. Dynamic data in the backup area during the preservation can support the remote download, which is convenient for offline storage.

In the processing layer, due to the use of edge computing technology in the storage layer, the data is transmitted to this layer in a standard data structure, so the central database can directly calculate the core functions without preprocessing the data, which reduces the pressure of the processing layer on the server hardware and software.

4. Conclusions

In this paper, the topological structure of the ubiquitous IoT distribution network in power system is studied. The proposed distribution network topology takes the energy router as the core equipment, and has flexible and controllable characteristics and the characteristic of AC and DC hybrid access. At the same time, independent of the information communication network of the power grid, an independent communication network is established for the IoT data between users and devices, which can not only guarantee the reliability of the power network operation, but also satisfy the transmission and storage of mass data. With the increasing diversity of access systems in the future power grid construction, especially the development and application of a lot of renewable energy, the distribution network topology will have a lot of application space.
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