Composition Form and Function Configuration of Intelligent Terminal Based on Edge Computing for Power Internet of Things

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Abstract. The intelligent terminal is a key device in the Power Internet of Things (PIOT), which plays a core role in the process of accurately sensing the state of power equipment and adjusting the user's electricity behaviour in real time. As a decentralized computing architecture, edge computing plays an important role in improving the data processing capacity and operation reliability of PIOT. This paper describes the operation process of PIOT based on edge computing, by studying the form of intelligent terminals in the field of power transmission, distribution and consumption, putting forward the basic configuration, specific function and principles of intelligent terminal. Combined with the operation characteristics and actual demand of power system, the application analysis of information perception ability and online control ability of intelligent terminal is carried out.

1. Introduction
With the increasing proportion of renewable energy in the total power generation, the operation characteristics and composition of the power system have undergone significant changes, and it is increasingly necessary to realize real-time monitoring of the operation state of the power equipment and online control of the power consumption behavior of power users. In 2019, State Grid Corporation of China proposed the idea of building a ubiquitous electric power Internet of things [1], aiming at realizing accurate perception of electrical quantity, state quantity and physical quantity by deploying intelligent terminals, improving the power system on-line transmission of electricity data and real-time adjustment control ability.

Edge computing is the downlink of cloud service function and the uplink of Internet of Everything service function [2], which is an important theoretical basis for the construction of Internet of Things (IOT). As a decentralized computing architecture, it transfers the computing of applications, data and services from the central node to the edge node of the network logic for processing, which can greatly improve the data processing efficiency [3].

Edge computing has already had some preliminary applications and assumptions in power systems. In the field of power supply and demand, household energy gateway, non-intrusive load monitoring system and orderly electricity management system have obvious demand for edge calculation [4]. Automated Demand Response Edge Computing (ADR-EC) node layered architecture model [5] can be designed based on the edge computing framework proposed by The European Association for
Standardization of Telecommunications. The application of edge computing collaborative architecture in the user-side intelligent electricity system can solve the load overload problem caused by multiple high-power loads working at the same time [6]. The active distribution network information physical system based on edge computing has significant advantages in key indicators such as real-time service, data optimization, application intelligence, security and privacy protection [7].

By studying the operating principle of the power Internet of Things and the theoretical basis of intelligent terminal networking, this paper constructs its constituent forms in different scenes and designs the functional configuration scheme of terminals. Combined with the operation characteristics and use demand of power system, the application analysis of terminal online control ability and information perception ability is carried out.

2. Power Internet of Things and edge nodes

In the Power Internet of Things (PIOT) based on edge computing architecture, intelligent terminals as edge nodes participate in the composition of the Internet of Things. This section will analyze the operating principle of PIOT based on edge computing, and clarify the role and significance of intelligent terminals in the PIOT.

PIOT is a smart service system featuring comprehensive state perception, efficient information processing, convenient and flexible application [8]. The system needs to use edge computing technology to build a distributed open platform to improve the system's data processing and control capabilities. The PIOT based on edge computing builds an open platform integrating network, computing, storage and application on the side close to data sources or devices to provide services for power users and power grid regulation nearby. Edge node refers to any device with computing resources and network resources between the source of data generation and the cloud center [9], which assumes the computing tasks under edge computing architecture and as the basis for transmission and networking. In the PIOT, intelligent terminals are used as edge nodes to achieve lower delay and higher bandwidth, so as to meet the real-time requirements of power system supply and demand balance. The operation process of PIOT based on edge computing is shown in Figure 1.

![Figure 1. The operation process of PIOT based on edge computing](image-url)

The PIOT under the edge computing architecture will greatly release the latent power everywhere, reduce the power supply cost, and provide the conditions for power sharing among producers and consumers. Edge computing technology will become the reliance and support for the realization of smart power grid and the revolutionary development of energy production and consumption with the Internet of Things, cloud computing, big data, artificial intelligence and other technologies.
3. The composition form of intelligent terminal

In this section, the configuration and working mode of PIOT terminals will be analyzed in combination with the edge computing network structure under different application scenarios.

3.1. Power transmission and transformation field

The application of PIOT technology in the field of transmission is mainly reflected in the monitoring of state of transmission line [10] and line safety maintenance and control work [11]. In order to meet the bandwidth, delay, reliability and safety requirements of the communication network of the transmission line terminal equipment, the coupling network based on the cascade topology wireless Mesh and optical fiber composite overhead ground wire optical transmission can be adopted. The real-time monitoring function puts forward higher requirements on the fault-tolerant capability of the network. To solve these problems, flat communication network structure and wired/wireless dual-channel heterogeneous networking technology can be adopted.

The PIOT is mainly used in smart substation in the field of power transformation, aiming at accurate real-time monitoring of the status of substation equipment and solving the problem of insufficient fault diagnosis function [12]-[14]. The main function of substation equipment temperature monitoring terminal equipment is to form an intelligent visual Internet of things based on vision sensors, processors and transmission systems to accurately and real-time detect and locate the temperature anomaly area of substation equipment. In case of abnormal operation or failure, the monitoring terminal of substation fault diagnosis and safe operation can process the original data through edge computing terminal to reduce transmission bandwidth and processing cost.

3.2. Power distribution field

The application of IOT technology in the field of power distribution includes the monitoring of power distribution equipment and its operation state, fault location and asset management, which requires intelligent upgrading of power distribution network with modern communication means and IOT technology [15]-[16]. The terminal equipment of active distribution network mainly includes data transfer unit (DTU), distribution transformer supervisory terminal unit (TTU), feeder terminal unit (FTU), etc., to perform the monitoring and collection of electrical quantity, switch position, abnormal signal and other parameters. to determine the fault location and cut out the fault section, provide the basic information of load redistribution for restoring power supply, and significantly reduce the amount of data during fault identification and processing.

The asset management of distribution network is realized through radio frequency identification technology (RFID). By utilizing the characteristics of non-contact reading and writing, RFID readers are placed in the area where the equipment is centralized, and the fixed assets in the area are checked regularly.

3.3. Intellectualization of power using

The application of IOT technology in the residential electricity sector mainly involves low-voltage meter reading, electricity safety, smart home, smart charging, etc. [17]-[18]. Electricity service system is an important part of PIOT construction on the user side. The edge computing terminal in this system is mainly set on the user's smart electricity meter to calculate the electricity consumption data collected by the user. For the residential intelligent electricity system equipped with household photovoltaic power generation device, the edge computing node is set in the terminal of the platform such as photovoltaic inverter and intelligent electricity meter, and the collected data is calculated locally in a distributed way.

The edge computing architecture for residential smart electricity is built on various terminals such as electricity information acquisition system, non-invasive load monitoring system and photovoltaic power generation system. The system data on the user side is uploaded to the corresponding cloud platform via the Internet or local area network (LAN).
4. Function configuration of intelligent terminal

The intelligent terminals of the Internet of Things in the power system adopt an open technology architecture, and the functions of the devices are defined by the software installed in the data analysis layer and the optimization decision layer. This section will combine the actual demand of power system and the advantages and disadvantages of the traditional terminal to propose the basic configuration principle of intelligent terminal, and carry out specific configuration design.

4.1. Basic configuration principle

The automatic terminals of the power system need to flexibly support and realize two-way interaction and coordinated control [19]. Combined with this requirement, the configuration of intelligent terminals should have three basic characteristics: hardware platform, software application functionalization and terminal standardization [20]-[21].

Intelligent terminals in PIOT should encapsulate data acquisition interface, communication interface and control interface, and design hardware platform based on virtual container technology. The hardware platform can adjust the main control module according to different business requirements, to realize business functions by means of software definition and improve the independence between application functions. To establish application function application market based on mobile Internet idea, in order to show the advantages of easy maintenance and convenient economy under the condition of low voltage grade and distributed architecture. Intelligent terminals of PIOT should have the functions of interconnection, intercommunication and interoperation between terminals, which is necessary to standardize the design of hardware interface, operating system, communication standard, data storage and other functions.

At the present stage, the intelligent terminals of PIOT with operating system and containerized virtualization technology usually require the minimum CPU frequency of 600MHz and the storage space of more than 1GB.

4.2. Specific function configuration

4.2.1. The network hardware.

Considering the supporting role of terminal devices in user information collection, online optimization and control system, it is necessary to make PIOT terminals compatible with various remote network interfaces, including at least: RJ-45 interface, to provide a stable and economical network connection architecture for ordinary users in an urban environment with complete infrastructure; Fiber Distributed Data Interface, to be suitable for multi-network environment and has important application value in the construction of IOT; RS-485 interface, to realize intelligent instrument interconnection and low-loss data transmission in power grid.

4.2.2. LAN compatibility.

In order to adapt to the compatibility impact that different forms of LAN networking may have on the composition of the PIOT, intelligent terminals should have a variety of network optional access functions [22]. The compatible function of wireless LAN should be reflected in the wireless communication module of dual-mode application. General Packet Radio Service (GPRS) mode should be used to ensure the real-time performance of terminal data exchange, while Narrow Band Internet of Things (NB-IoT) mode expand the number of terminals participating in data exchange and ensure the networking capacity of local area network. The compatibility of intelligent terminal to wired LAN should be reflected in the hardware design of multiple network interfaces and the flexible combination of different topology types.

4.2.3. Signal input and output interface.

In a smart terminal, the communication functional Interface between the terminal and external devices has been integrated into the Standard I/O Interface, so the PIOT terminal should have the
corresponding Interface configuration. The most commonly used standard serial communication interfaces are RS-232C and RS-422/423, which are different in transmission speed and continuous distance.

4.2.4. Local program Settings.
In order to improve the ability to resist risks of PIOT system, some on-site program setting functions should be provided in terminal configuration, such as system operation status query and fault alarm function, abnormal electrical behaviour and equipment control warning function, manual local control and temporary storage function of electricity information, to improve the reliability of the system under abnormal working conditions like network interruption and transmission delay.

5. Application analysis of intelligent terminal
One of the important functions of PIOT is to complete the intelligent perception and on-line adjustment management of power equipment and power consumption process [23], which puts forward extremely high requirements for the real-time and reliability of network transmission and the integration ability of distributed terminals [24]. This section will combine several possible application scenarios to explain the relationship between terminal function configuration, information perception and online regulation.

In industrial enterprises and their production sites, users adjust the mobile load through the given real-time electricity price [25], which requires terminals to have a good network hardware foundation and compatibility with sensor signals, and to design the corresponding program preparation in case of emergency.

Residents and ordinary urban users mainly adjust the state of power equipment in response to the change of price information to optimize the power consumption behavior [26], which requires the terminal to have corresponding network hardware conditions and flexible LAN combination ability, and timely process diversified input and output signals.

The virtual power plant may appear in PIOT [27], which contains a large amount of demand-side resources and distributed energy, requiring terminals to have real-time interaction of information and good distributed performance, to meet the needs of online computing and regulation.

Through the analysis of several application scenarios above, the functional configuration of the PIOT terminal basically meets the use demand, and better adapts to the requirements of the online optimization and regulation of the power consumption behavior and power consumption equipment.

6. Conclusions and future work
This paper describes the operation process of PIOT based on edge computing, determining the basic configuration principle and specific function configuration of intelligent terminal by studying the working mode and composition form of terminal in the power system. Combined with the operation characteristics of power grid and future development needs, the information perception ability and online control ability of intelligent terminal are analyzed.

It is worthwhile to continue to study the auxiliary role of intelligent terminals in demand-side resource scheduling and the collaborative control of devices in the PIOT. In order to improve the efficiency of power resource allocation and save the cost, it is necessary to carry out real-time control and scheduling of demand-side resources and power equipment connected to the PIOT. It is necessary to study how to improve the technical design of intelligent terminals in real-time and controllability.

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