Cloud-Edge Cooperation Data Acquisition and Processing Method of Multi-energy Systems

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Abstract. There are tens of thousands of power equipment and network equipment in the power grid system, including a large-scale heterogeneous network composed of intelligent terminals, sensors, databases and so on. These heterogeneous networks often belong to different business systems with a different logic and will produce a considerable amount of data at the edge of the network all the time. By studying the big data monitoring and analysis technology for enterprise operation decision-making, we can explore various values in heterogeneous data of power grid. For different types of data, the value in historical data is analyzed through algorithms such as data analysis, data mining and machine learning, and the law and value in real-time data are found through flow calculation.

Keywords: Cloud-edge cooperation · Data acquisition · Energy management

1 Introduction

To further promote green, low-carbon and sustainable development of energy, comprehensive energy services have developed rapidly in the world in recent years, which has triggered profound changes in the energy system and become the focus of new strategic competition and cooperation among countries and enterprises. At present, the power industry has three main characteristics and needs to speed up the service transformation: first, more and more new energy needs unified access to the network such as photovoltaic, wind power and hydropower; second, more and more new businesses adapt to the emergence of various business forms such as energy sales services, information services, market transactions and intelligent power grid value-added services, The third is the increasingly complex power grid dispatching and maintenance, which requires the use of ICT technologies, such as the Internet of things and big data to build an information management and control platform, realize the deep integration of power flow, information flow and business flow, ensure the supply and demand balance of multi-energy and support the transformation of comprehensive energy services. At present, with the development of integrated energy service business, there are unprecedented challenges to energy perception from breadth to depth, as illustrated in Fig. 1.

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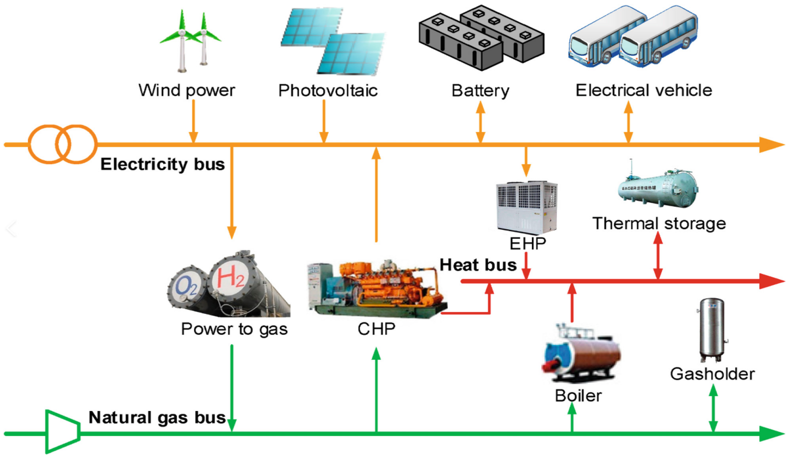

Fig. 1. A typical multi-energy system

At present, energy perception equipment still faces the following problems:

- There are barriers to energy collection. Today's energy collection is characterized by single energy collection, island storage, and chimney data upload. There are barriers to energy collection.
- The existing terminal technology is backward. The existing terminal is bulky, difficult to install, expensive, and single communication mode, which cannot meet the needs of large-scale distribution.
- The networking operation and maintenance costs are high, the communication technology is single, the communication distribution is dense, the equipment and networking cost is high, and the business upgrading needs to replace the hardware or upgrade to the site for debugging, which costs a lot of operation and maintenance.
- The operation management level is low, and the energy management is only supervised without control or manual control, which cannot realize the automatic diagnosis and optimal regulation of energy system utilization strategy, resulting in great waste.
- Low intelligence, unable to make independent decisions, need to upload a large amount of data, but great pressure on communication bandwidth and cloud platform computing, and cannot generate real-time control strategy according to real-time working conditions.
- The security is low. Due to the risk of insufficient security protection of existing equipment, external personnel can tamper with data and control equipment to threaten the security of the power grid.

Therefore, it is urgent to carry out technical research on energy consumption data acquisition and monitoring in the context of comprehensive energy, build data acquisition and monitoring system with comprehensive state perception and processing.

2 Related Work

2.1 Data Acquisition

The work in [1] introduced the structure, acquisition principle, and networking mode of the data acquisition system as a whole, and designs and implements a data acquisition terminal, including detailed hardware design, underlying software design, and application program design of the data acquisition system, The feasibility of the software and hardware design of the data acquisition system is verified by the indoor environment data acquisition system. The study in [2] described the design and implementation of the pulse acquisition circuit of acquisition terminal, as well as the design of each software module of the acquisition terminal. This acquisition terminal can not only collect pulse watt-hour meter but also collect watt-hour meter with RS485 interface. The work in [3] provided a new design method of terminal unified management interface with good flexibility and expansibility, which provides bottom communication support for heterogeneous terminal unified management systems in next-generation networks. For the applicability of the wireless communication module, the authors in [4] designed and developed a LoRa wireless communication module based on the relevant specifications of the power consumption information acquisition system, and uses the actual watt-hour meter and watt-hour meter protocol test software to carry out the actual meter reading test. The experimental results show that the technical indexes and meter reading of the module meets the design requirements, it can be applied in the future power wireless meter reading. The work in [5] analyzes the access mode and security problems of mobile terminals of power grid enterprises, puts forward the security protection countermeasures of mobile terminals of power grid enterprises, and puts forward corresponding feasible schemes for power grid enterprises to widely carry out mobile terminal business and application and improve the security of information intranet of power grid enterprises.

2.2 Multi-energy Data Acquisition and Processing

The studies in [6] have realized enterprise energy consumption data collection through Internet of things technology, global positioning system and wireless sensor network technology. However, there are few types of monitored energy, so the collected energy information can only be subject to simple statistical analysis, rather than deeper data mining. The work in [7] applied the Internet of things technology to the real-time monitoring of energy conservation and emission reduction in industrial parks and describes the real-time monitoring system of energy conservation and emission reduction in detail. However, the monitoring of the system can only be aimed at the location where sensors can be fixed, and the processing and analysis of the collected energy data are not sufficient, so it does not have the ability of energy conservation management. In [8], the Internet of things technology combines the upper computer monitoring platform and network and uses the fault diagnosis system and various monitoring equipment running on-site to obtain the operation data and operation status of high-frequency power supply in real-time from a long distance. However, the system designed in this document adopts C/S architecture.

2.3 Internet of Things Framework

The work in [9] divided the Internet of things into three parts from top to bottom: perception layer, network transmission layer and application layer. The sensing layer of the Internet of things is at the bottom of the Internet of things architecture, which is composed of various sensors, control modules, networking communication modules and intelligent gateways for accessing sensors, aggregating data, and connecting the sensing layer and the network layer. The network layer is composed of the Internet, personal local area network, mobile communication network, network transmission system and data resource integration and open business platform, which provides open network and data resource integration and opening services for the Internet of things. The application layer is the user-oriented "interface" of the Internet of things. Combined with the specific industry needs, it constructs the Internet of things application environment monitoring, natural disaster early warning, smart home and intelligent transportation for all walks of life-based on the perception layer and network layer. In [10], the work described the development process of Lora, introduces three-terminal devices of Lora modulation and LoRa-WAN, finally analyzes the key technologies of Lora, describes in detail and lists some specific examples of Lora application. The study in [6] analyzed and summarized the current RS485 communication interface design scheme of intelligent electric energy meter, and puts forward suggestions and solutions for the RS485 interface design from the aspects of RS485 chip itself, data receiving sensitivity, carrying capacity, communication reliability, and so on. The study in [11] designed a wireless gateway based on ZigBee and WiFi to realize ZigBee data interaction of intelligent terminal in home environment and remote. The authors in [12] introduced the LoRa technology and compared different wireless communication technologies. The work in [13] discussed the NB-IoT enhancement technology under the Internet of things coverage, analyzes the application of Nb-IoT Internet of things coverage enhancement technology, puts forward a method to evaluate NB-IoT technology based on the coverage enhancement technology, and focuses on the coverage enhancement of repeated transmission. The enhancement technologies in the current 3GPP proposal are simulated and compared.

3 Cloud-Edge Cooperation Data Acquisition and Processing

3.1 System Architecture Design

The network system of multi-function acquisition on the user side is shown in Fig. 2.

The network architecture is a hierarchical network structure, including sensor node, gateway node (intelligent acquisition terminal), the local base station (energy controller), and transmission network and finally connected to the cloud service platform. To obtain data more accurately, the distribution of sensor nodes is usually very dense, which may be distributed in different monitoring areas, which constitutes multiple sensor networks. In the practical application of this sensor network system structure, the data is measured by the sensor node, and then transmitted to the network management node (intelligent acquisition terminal), and then the acquisition terminal transmits the collected data to the edge controller.

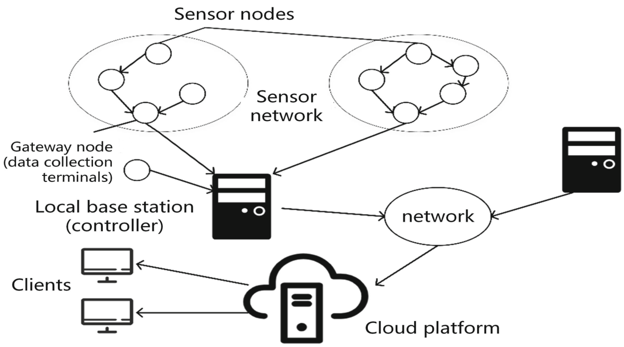

Fig. 2. Cloud-edge cooperative data acquisition and processing framework

Sensor nodes can carry out data calculation and data communication. They can realize data fusion in sensor networks, reduce data traffic and alleviate the forwarding burden of sensor nodes. The gateway node is mainly responsible for collecting the data transmitted from the sensor node. All gateway nodes will connect with the transmission network and transmit the collected data to the superior node. Sensor network includes sensor nodes and gateway nodes. The whole sensor network plays the role of data preprocessing and data uploading.

The base station node is a controller connected to the cloud node with certain computing, storage, analysis and decision-making capabilities. It is mainly responsible for collecting the data uploaded from the gateway node and sending the data to the cloud data processing center through the transmission network. At the same time, it is also a local database, which can cache sensor data in the local database. The base station node can process and analyze local data and realize local decision-making.

3.2 System Functionalities and Specifications

(1) Energy consumption acquisition

Using the existing intelligent electric energy meter, gas meter, water meter and other collection technologies and the collection terminal in the energy efficiency monitoring subsystem of industrial, commercial and residential users, collect the user's energy consumption data and the data of multiple accounting quantities of the intelligent collection terminal by installing the collection module in the user or replacing the intelligent collection terminals.

(2) Multi-energy data analysis and processing

On the one hand, the collected energy consumption data should be intuitively displayed to users to let users understand their energy consumption level; on the other hand, it should be used as the data basis for evaluating users' energy-saving levels. The data collected by the intelligent acquisition terminal is transmitted to the energy controller after multi-energy data aggregation for centralized storage and local processing. When the intelligent acquisition terminal and the energy controller are in the local LAN, it is considered to transmit the sensing layer data to the energy controller through RS-485, WiFi and LoRa. Data analysis is the core of energy data acquisition and monitoring systems. To process, store and display energy efficiency data, analyze whether users' energy consumption behavior is reasonable and feasible through data evaluation methods. Further, the user energy consumption mode can be regulated according to the user energy consumption data, and the optimal regulation strategy can be automatically obtained according to the user energy consumption mode. The manager can evaluate the information of the energy efficiency management scheme provided by the user. Among them, it is necessary to formulate a comprehensive and reasonable evaluation system for user energy consumption. Machine learning techniques can be adopted in the data process, e.g., Random Forest based algorithms, as illustrated in Fig. 3.

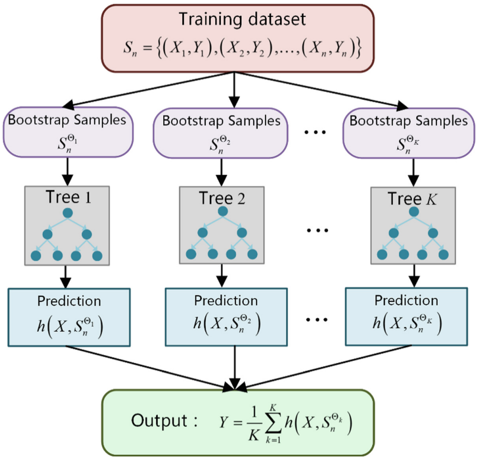

Fig. 3. Basic structure of Random Forest method

(3) Equipment monitoring

At the system terminal, the energy consumption status of each device inside the user is visually presented to the user through the software management system. The user can select to add, change and delete internal energy consumption devices in the user interface of the system according to their own needs. It can not only realize the operation through the web but also control the energy consumption devices through control devices such as terminal software, such as setting timing startup Stop and control the equipment remotely through the terminal. You can view the working conditions of the energy controller, as well as the energy consumption and data analysis results of various energy-consuming equipment in real-time, to obtain the local optimal control strategy. Also, the edge computing devices can be adopted, as shown in Fig. 4 and Fig. 5.

(4) System function realization process

According to the simple description of the system hierarchy and main functions, the functions to be realized by the system mainly include completing the real-time

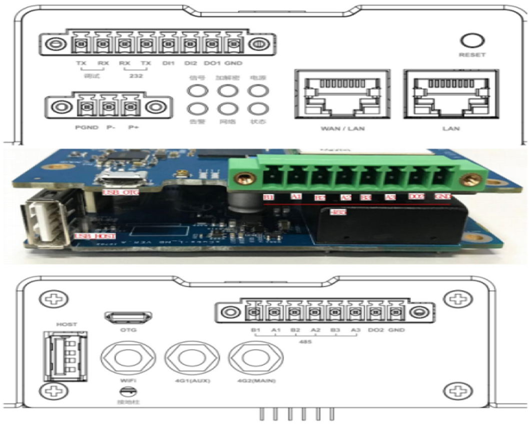

Fig. 4. A basic design of the edge device

Fig. 5. Installation of the monitoring devices

acquisition, processing and analysis of user energy consumption data and completing the local energy efficiency analysis and optimization regulation. For example, the energy consumption of a typical data center can be described as follows:

The components of the server include CPU, memory, hard disk, network, etc. the required components are configured reasonably according to the needs of the service. The existing nonlinear relationship model is given in (1).

$$P_{used} = P_{idle} + \left(P_{busy} - P_{idle}\right) \times u \tag{1}$$

where P_{used}, P_{idle}, P_{busy} and u represent the actual power, idle power, full operation power and utilization rate.

The above can be further simplified as follows:

$$P_{used} = \beta \cdot P_{busy} + (1 - \beta) \cdot P_{busy} \cdot u \tag{2}$$

Further the energy consumption of data center can be described as

$$E = \int_{t_1}^{t_2} P_{used}(t)dt \tag{3}$$

The idle operational energy consumption is

$$DE_j = \int_0^{T_j^{dormancy}} P_j^{dormancy} dt \tag{4}$$

where $P_j^{dormancy}$ and $T_j^{dormancy}$ are the idle energy and idle time.

4 Conclusions and Remarks

In this paper, through the research on the key technologies of data acquisition and monitoring of energy consumption control system, master the technical architecture of energy consumption data acquisition and monitoring in multiple scenarios such as commercial buildings, industrial enterprises and park services, the dynamic perception and online analysis technology of energy consumption information based on Internet of things and edge computing, and the application method of edge computing gateway in power Internet of things, to realize business sinking Reduce the underlying data processing from the cloud to the ground, solve the problem of low resource utilization efficiency and time processing efficiency under a single cloud computing model, and provide support for building a secure, intelligent, professional and integrated Internet of things management platform.

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References

1. Arnaudov, R.I., Dochev, I.N.: Functional generator and data acquisition system controlled by internet. In: 2005 IEEE Intelligent Data Acquisition and Advanced Computing Systems: Technology and Applications, pp. 276–278 (2005)
2. Weng, Y., Wang, X., Qelger, Ma, G.: Data acquisition terminal application design and development based on the Android platform. In: 2012 Fifth International Conference on Intelligent Networks and Intelligent Systems, pp. 257–259 (2012)
3. Zirui, G.: Design and implementation of financial information management system for mobile terminal. In: 2020 5th International Conference on Smart Grid and Electrical Automation (ICSGEA), pp. 354–357 (2020)
4. Ke, K., Liang, Q., Zeng, G., Lin, J., Lee, H.: Demo abstract: a LoRa wireless mesh networking module for campus-scale monitoring. In: 2017 16th ACM/IEEE International Conference on Information Processing in Sensor Networks (IPSN), pp. 259–260 (2017)

5. Hu, H., et al.: The development and application of dynamometer card measurement and analysis system based on Android platform. In: 2016 8th International Conference on Computational Intelligence and Communication Networks (CICN), pp. 150–154 (2016)
6. Li, G., et al.: Energy efficient data collection in large-scale internet of things via computation offloading. IEEE Internet Things J. **6**(3), 4176–4187 (2019)
7. Che Soh, Z.H., Hamzah, I.H., Che Abdullah, S.A., Shafie, M.A., Sulaiman, S.N., Daud, K.: Energy consumption monitoring and alert system via IoT. In: 2019 7th International Conference on Future Internet of Things and Cloud (FiCloud), pp. 265–269 (2019)
8. Ortega, M.G.S., Rodriguez, L., Gutierrez-Garcia, J.O.: Energy-aware data collection from the internet of things for building emotional profiles. In: 2018 Third International Conference on Fog and Mobile Edge Computing (FMEC), pp. 234–239 (2018)
9. Lin, J., et al.: A survey on internet of things: architecture enabling technologies security and privacy and applications. IEEE Internet Things J. **4**(5), 1125–1142 (2017)
10. Wu, F., Miao, Z., He, C.: Remote monitoring system for intelligent slaughter production line based on internet of things and cloud platform. In: 2020 11th International Conference on Prognostics and System Health Management (PHM-2020 Jinan), pp. 538–542 (2020)
11. Pan, G., He, J., Wu, Q., Fang, R., Cao, J., Liao, D.: Automatic stabilization of Zigbee network. In: 2018 International Conference on Artificial Intelligence and Big Data (ICAIBD), pp. 224–227 (2018)
12. Edward, P., El-Aasser, M., Ashour, M., Elshabrawy, T.: Interleaved chirp spreading LoRa as a parallel network to enhance LoRa capacity. IEEE Internet of Things J. **8**(5), 3864–3874 (2021)
13. Chung, H., Lee, S., Jeong, J.: NB-IoT optimization on paging MCS and coverage level. In: 2018 15th International Symposium on Wireless Communication Systems (ISWCS), pp. 1–5 (2018)