Design of Wireless Monitoring System for Power Terminal Equipment based on NB-IoT

Lei Sun¹, Xianhua Hu²*, Jinxuan Li¹ and Tairong Xie²

¹ Guangzhou Power Supply Bureau Co., Ltd, Guangzhou, Guangdong, 510620, China
² Guangdong Yuanpeng Network Technology Co., Ltd, Guangzhou, Guangdong, 510000, China

*Corresponding author’s e-mail: 15602279647@163.com

Abstract. The application of Low-Power Wide-Area Network (LPWAN) technology in wireless monitoring of power terminal equipment is studied in this paper. From the aspects of hardware and software design of monitoring terminal, communication protocol, remote data management cloud platform, the wireless monitoring system of power terminal based on Narrow Band Internet of Things (NB-IoT) is designed in detail. STM32L151 is chosen as the main controller of the monitoring terminal owing to its low power consumption. After simple edge calculation and data packaging, the terminal equipment status information is reported to the remote data management platform via NB-IoT network based on system setting. The platform supports various functions such as a variety of terminal access methods, terminal identity authentication, parameter configuration, data forwarding, and terminal abnormal data information reporting and so on. In order to improve the User Datagram Protocol (UDP) transmission reliability, the terminal drop detection mechanism is designed on UDP communication protocol. Eventually, the system is applied in monitoring power terminal equipment status such as transmission and distribution pole tower, power well cover, cable trench cover, knife brake of distribution line, etc. The experimental results show that the power terminal monitoring system based on NB-IoT can achieve unified access and centralized management of power equipment status information in different power scenarios, and this system greatly enhances the reliability and efficiency of power system terminal equipment operation and maintenance, and has value in engineering.

1. Introduction

With the development of smart grid, Internet of Things technology has been widely concerned in the energy and power industry, such as the application in the field of transmission line online monitoring, intelligent inspection, intelligent user service, electric vehicle auxiliary management, etc. In the power system scenario, it is also necessary to monitor the relevant equipment in the process of power generation, transmission, transformation and distribution [1]. However, the devices in these scenarios are widely distributed and highly decentralized, and the data acquisition terminal has the characteristics of difficult power supply, difficult connection, slow state transformation and low acquisition frequency. Therefore, the ‘small data’ in the power system cannot be connected and acquired quickly, flexibly and cheaply. This is a short board of smart grid construction and application, and also an urgent connection problem to be solved in the development of energy Internet.

In the information technology of the Internet of things, the traditional wireless access technology
represented by short-range wireless access and mobile cellular network, which has been limited in power consumption, cost, especially in coverage breadth and depth. Therefore, it is unable to provide an ideal communication method for the deep application scenario of power grid with large number of terminal nodes, wide distribution and small data transmission [2]. LPWAN, as a new technology in the information technology field of the Internet of things, has the technical characteristics of wide coverage, massive connection, low cost and low power consumption [3], and it makes up for the above-mentioned shortcomings of traditional wireless access technology in some applications.

LPWAN can be divided into two categories: One is LoRa, SigFox and other technologies working in unauthorized spectrum; The other is the 2/3/4G cellular communication technology supported by 3GPP working in the authorized spectrum, such as EC-GSM, LTE Cat-m, NB-IoT, etc[4]. From the perspective of global application share at this stage, Lora and NB-IoT have a bright future.

After the actual deployment of these two technologies in a specific project and running tests, it is concluded that NB-IoT has the following advantages over Lora[5]: NB-IoT network is realized by three domestic network operators through dedicated frequency band, which has obvious advantages in stability and reliability; NB-IoT in domestic market has mature civil modules and less network deployment workload, while Lora needs independent networking; The strength of LPWAN communication signal depends on the operation power of base station. Lora needs to deploy routing base station independently. In many cases (especially in urban buildings), the communication signal attenuation is large, so, NB-IoT has greater advantages; Lora base station, as the data route deployed by users independently, needs to receive node data and report it to remote server through other ways, so there is a certain risk in data security; When there are multiple Lora network signals, there will be interference between different signals.

Based on the above analysis, the research of this system is oriented to the application of LPWAN adaptation with deep coverage of power grid. After the comparative analysis of LPWAN technology in unauthorized frequency band and authorized frequency band, NB-IoT network is selected to carry out the research of power system equipment and line monitoring, and design the monitoring terminal based on this network. The power system object of this system includes: transmission and distribution pole tower monitoring, power well cover monitoring, cable trench cover monitoring, distribution line switch temperature monitoring and many other equipment and scenes.

2. Design of power equipment monitoring terminal
This system is based on the NB-IoT monitoring terminal to achieve the data collection of various application scenarios and equipment. The monitoring terminal performs simple edge calculation and data packaging for the collected equipment data, and reports the data to the remote data management platform according to the system setting.

2.1. Hardware design of power equipment monitoring terminal
Because this system aims at many equipment and scenes in the power system, such as transmission and distribution pole tower monitoring, power well cover monitoring, cable trench cover monitoring, distribution line switch temperature monitoring, etc. In order to achieve the function of a terminal hardware adapting to multiple scenes, the monitoring terminal hardware is designed into two parts which are the main hardware and external sensors. The main hardware is mainly composed of main control module, communication module, power module and external bus communication module. STM32L151 is chosen as the main controller, and BC35-G module is chosen as NB-IoT wireless communication module. The main hardware is connected with external sensors by RS485 bus. Among external sensors, SHT20 temperature and humidity sensor is used for environmental monitoring in power well cover and cable trench cover; The angle sensor of adxl345 is used for monitoring the abnormal movement of power trench cover plate, cable trench cover plate and transmission and distribution pole tower; The model T10S-B-HW infrared temperature sensor is applied in monitoring the temperature of the power switch and other strong electric equipment. The hardware structure of the monitoring terminal is shown in figure 1.
2.2. Software design of power equipment monitoring terminal

The software design of the monitoring terminal is designed with a layered architecture, which includes the hardware module, the bottom driver layer, operating system layer and user task layer, the software architecture of the monitoring terminal is shown in figure 2. The program is mainly includes four tasks, namely, watchdog refresh and flag monitoring task, system status light task, debug sensor mode task and data acquisition and communication task, and using FreeRTOS embedded real-time operating system to schedule task. As the core task of monitoring terminal, data acquisition and communication task has the highest priority. The task of data acquisition and communication is to collect sensor data periodically and make a simple judgment on the data. If the data is abnormal, the task will pack the data package according to the protocol requirements and upload it to the remote data management platform. Otherwise, the monitoring terminal uploads sensor data to the remote data management platform in a fixed period.

2.3. Design of data communication protocol

UDP has the characteristics of less traffic consumption in data transmission process, suitable for small data transmission, no need for continuous connection, etc [6]. Therefore, this system employs private protocol based on UDP to encapsulate data packets.

Packets follow a minimum frame length of 13 bytes and a maximum of 1024 bytes, where, the starting position of checksum is all information from ‘package length’ to the end of data field. The algorithm of checksum follows RCF1071. In order to reduce communication cost and ensure the consistency of data, the three fields of CMD + data length + data field are combined into a sub package. A complete message can be composed of multiple sub packages and package length is the number of subsequent sub packages, where 1 is the minimum.

The data transmission based on UDP protocol is not connected with the platform, but in the form of sending data packets directly. In order to ensure the reliability of data transmission in the process of communication, through the data exchange of communication packets, a drop detection mechanism is applied in the monitoring terminal. The idea of this mechanism is that when the monitoring terminal sends packets to the platform, the platform needs to respond to ACK packets. The main communication process is as follows:
- Determine the initial value of system transmission interval time (reporting period) and message retransmission period and add them into the communication packet;
- In each period, the monitoring terminal collects the data, then encapsulates the data into the communication packet and sends it to the remote data management platform;
- The terminal will wait for the platform's response. If the response is successful, the communication is completed. Otherwise, the data packet will be resent;
- If data-sending fails in three times, it is considered that the terminal fails to connect to the network, and the system will be restarted after recording the relevant logs.

2.4. Remote data management platform
The system can be used in many different scenarios because the system has different devices based on different protocols. Therefore, the remote data management is a service system which supports multiple terminal access modes so as to realize the communication mode processing, data collection and management of multiple terminals and configure different alarm thresholds according to different scenarios. In addition, the platform also supports terminal identity authentication, parameter configuration, data forwarding, abnormal data reporting and other functions, providing a safe, reliable and stable terminal data access channel and an open terminal service and application service interface for the upper application. The system architecture of the remote data management platform is shown in figure 3. There are four layers: access layer, capability layer, service layer and application layer.

![System architecture of data management platform.](image)

In this system, the terminal data is uploaded to the remote data management platform in the cloud server through NB-IoT network. Externally, the cloud platform only implements pure data processing services, does not involve interface implementation, and provides a unified API interface, so that each control platform can develop interface according to its own platform characteristics, and does not affect the realization of functions. In order to realize the interaction between the user and the platform, the database is designed on the server side to archive and store the platform data. To realize data visualization, JAVA language, spring cloud technology and database technology are employed to design web interface, and display the archived data in the form of charts on the web side.

3. System operation results
The system can monitor various parameters of different equipment in different scenes of power system including transmission and distribution pole tower monitoring, power well cover monitoring, cable trench cover monitoring, distribution line switch temperature monitoring, etc. Temperature monitoring terminal of knife brake and the field test installation drawing is shown in figure 4.

The remote data management platform is mainly used for collecting and analyzing equipment data to provide customers with various data parameters of the current monitoring terminal operation. The platform is shown in figure 5. The longitude and latitude of the terminal location can be displayed in the platform. When the monitoring terminal sends alarm data, the color of the monitoring terminal is displayed in red on the map. The alarm results are displayed in a graphical interface, which is convenient for managers to capture the faulty equipment.
After four days of field installation and operation of the power well cover monitoring terminal, tower monitoring terminal and power knife brake temperature monitoring terminal, the monitoring terminal data flow of each scenario is shown in figure 6-9.

By adding a switch circuit of sensor power supply is to optimize running power consumption of the monitoring terminal. The hardware controller can control MOS transistor to turn off sensors’ power supply so as to reduce their power consumption when the system in the sleep state. In addition, RS485 interface is adopted in the in the hardware interface of the sensor to reduce the power consumption as well. The experimental results show that the working current of the monitoring terminal is about 17μA,
and it can work for more than 5 years by using the general lithium battery parameter 1wmA. The operation power consumption statistics of each state of the system are shown in Table 1.

**Table 1.** Power consumption test results of monitoring terminal.

| Status/Process               | Duration | Average current | Maximum | Status/Process               | Duration | Average current | Maximum | Status/Process               |
|------------------------------|----------|-----------------|---------|------------------------------|----------|-----------------|---------|------------------------------|
| System attached network      | 37s      | 23.3mA          | 275mA   | 870μWh                       |          |                 |         |                              |
| Dormancy standby             | 5min     | 17.9μA          | 31.0μA  | 5.36μWh                      |          |                 |         |                              |
| Data collection              | Average 1s| 3.83mA          | 6.97mA  | 5.97μWh                      |          |                 |         |                              |
| Data reporting               | Average 23S| 39.8mA          | 211mA   | 940μWh                       |          |                 |         |                              |

4. Conclusion

The devices in the power system are widely distributed and highly decentralized. Meanwhile, data acquisition terminal has the characteristics of difficult power supply, difficult connection, slow state transformation and low acquisition frequency. Therefore, the ‘small micro data’ in the power system cannot be unified access and centralized management. In view of the above problems, this paper mainly designs the wireless monitoring system of power terminal equipment based on NB-IoT from the aspects of monitoring terminal software and hardware, communication mode, remote data management platform, etc. The system is applied in monitoring the status of power terminal equipment such as transmission and distribution pole tower, power well cover, cable trench cover, knife brake of distribution line, etc. The operation results show that the system can not only collect the status data of power equipment and upload it to the remote micro data management platform, but also alarm the abnormal data in time, giving full play to the low power consumption and wide coverage of LPWAN. It realizes the unified access and centralized management of the power equipment monitoring terminal, greatly reduces the routine and periodic equipment on-site inspection workload, and provides a good solution for some industries that cannot use the traditional equipment monitoring in specific scenarios.

Acknowledgments

This work was supported in part by Guangzhou Science and Technology Planning Project under Grant 201902020003, in part by China Southern Power Grid Science and Technology Project under Grant GZJKJXM20170032.

References

[1] Huaxi L and Qian D 2016 Research on key technologies of Internet of power transmissions and transformation equipment *Intelligent City*. 12 60-61.

[2] Zhe W, Hongda Z, Mingxia Z, Xiangpeng X, Hongfu X and Bipeng Z 2019 Application of power wireless private network in ubiquitous power Internet of Things *Electric Power*. 12 27-38.

[3] Li T and Shanhong W 2019 Application of LPWAN in power grid *Techniques of Automation and Applications*. 11.

[4] Qi Y, Yunyong Z and Gang A 2017 Comparative analysis of low-power wide area Internet of Things (LPWA) technology based on application scenarios *World Telecommunication*. 3 52-58.

[5] Yi Q 2018 The new pattern of Internet of Things opened by LoRa and NB-IoT technology *Modern Information Technology*. 006 197-198.

[6] Kun X and Liang Z 2019 The implementation of reliable data transmission based on UDP protocol *Science and Technology Innovation Herald*. 17 7-8.