Design and Implementation of 230MHz Communication Function for Smart Grid Inspection Terminal

Xiaodong Tu$^1$, Ruibing Zhang$^2$, Juan Wang$^3$, Yan Li$^4$, Chaoli Feng$^4$, Jianxin Chu$^4$, Weihua Gu$^4$, Yong Wang$^1$, Qian Li$^1$, Haibing Fu$^2$

$^1$State Grid Jiaxing Electric Power Supply Company, Jiaxing, Zhejiang, 314033, China
$^2$Potevio Information Technology Co., Ltd., Beijing, 100086, China
$^3$Zhejiang Huayun Information Technology Co., Ltd., Hangzhou, Zhejiang, 310012, China
$^4$State Grid Zhejiang Haiyan County Power Supply Co., Ltd., Haiyan, Zhejiang, 314300, China

Abstract: Smart grid inspection is a basic maintenance task for power equipment. Through inspection, the reliability and safety of power equipment can be improved, and the failure rate of power equipment can be effectively reduced. In order to improve the quality of smart grid inspections, this paper analyses the limitations of smart grid inspection terminals, proposes methods to expand the private wireless network communication capabilities based on the original terminals, designs and implements software and hardware, and develops prototype equipment. Finally, a verification test is performed based on the actual 230MHz wireless communication network, this proves that the new intelligent inspection terminal can work normally in a private wireless network environment. This paper describes the software design and hardware design ideas in detail, which can be used as a reference for the capacity expansion of various type of terminals in smart grids.

1. Introduction
With the maturity of 5G standards and the rapid deployment of commercial networks, Internet of Things (IOT) has gotten more and more attention with the development of social and economy, which has become a key research direction for achieving industrial intelligence and improving work efficiency in various industries [1]. Grid companies have also proposed to deploy their own IOT to meet the rapid development of smart grids. The deployment of the power IOT not only realizes the rapid connection of fixed data acquisition terminals, but also promotes more mobile applications, such as the development of smart grid inspection terminals [2]. The power IOT cannot be separated from wireless communication networks. Therefore, with the deployment of the power IOT, the inspection terminals also need to have the capability of communication in private wireless network.

2. Background analysis
Power grid inspection is a basic maintenance task for equipment. Through inspection, the reliability and safety of power equipment can be improved and the failure rate of power equipment can be effectively reduced. However, traditional grid inspection terminals often encounter no movement. The area covered by the CMCC network cannot guarantee the real-time transmission of inspection data, and it is important to increase the communication function in private wireless network accordingly [3].
Beginning in 2017, the State Grid Corporation of China has carried out a variety of private wireless network pilot in multiple provinces and cities. The 230 MHz band has been widely used as wireless working frequency band because of its excellent coverage performance, and the LTE-G 230MHz system is defined as an enterprise standard of the State Grid Corporation [4]. In view of this background, it is necessary to improve the design of the existing power grid inspection terminal and increase the communication capability in 230MHz private wireless network.

3. Design and implementation

3.1 Hardware design

The design goal is to increase the private wireless network communication function on the basis of the original inspection terminal, and expand the capacity by adding external communication modules. The communication module mainly includes a baseband radio frequency processing unit (BRU) and a carrier board unit for auxiliary work. The communication module communicates with the original interface of the device through a serial port. The module design is shown in the figure 1.

![BRU and Motherboard Diagram](image)

**Figure 1. The design of communication module**

The BRU board includes a baseband processing unit and a radio processing unit. The external interface of the BRU module includes a data communication interface, a debug serial port, a power supply interface, and an antenna interface [5].

The external module is designed as a thickened mobile phone case. The BRU and the carrier board unit are placed in the housing. The additional module is designed with an SMA standard antenna interface, and antenna can be connected. The prototype device is shown in the figure 2.

![Prototype Device](image)

**Figure 2. Prototype with 230MHz communication function**

3.2 Software design

3.2.1 External protocol design. Protocol stack between the terminal and the network includes several layers, the physical layer, the data link layer, and the Radio Resource Control layer (RRC). The protocol stack architecture is shown in the following figure 3.
3.2.2 Physical frame design. The 230MHz private wireless network works in the 223MHz-235MHz wireless frequency band, and the minimum channel bandwidth is 25kHz. The frame structure of the physical layer is designed to be 25ms.

![Physical frame diagram](image_url)

Figure 4. Physical frame
In order to fit the characteristics of the grid data, the transmission resources is designed to 3: 1, so each frame contains 1 downlink sub-frame and 3 uplink sub-frames, and each sub-frame is 5ms in length [8].

The uplink and downlink sub-frame conversion interval is 5ms, which can ensure the best interference suppression. These include DwPTS, GP and UpPTS messages. DwPTS is a downlink pilot message, UpPTS is an uplink pilot message, and GP is a guard interval.

4. Verification test
In order to verify that the inspection terminal can work through the 230MHz wireless network, design the test procedure: 1) power on the inspection terminal and attach it to the 230MHz wireless network; 2) Ensure that terminal successfully connects to the server, and get network latency with Ping command; 3) Test the inspection software.

Test results: After the terminal is attached to the 230MHz wireless network, it sends a ping command from the server side, and it can get the response normally, and the network latency is about 170ms; the inspection software runs smoothly, and it can interact with the remote server for data processing.

5. Summary
This article analyses the existing problems of the power grid inspection terminal, designs and implements the 230MHz communication function, develops a prototype, and performs verification tests at the power grid company. The verification results meet the design expectations, and the research result has positive reference value for further evolution of the power IOT.

Reference
[1] Ma Y, Li B, Hu Q. (2019) Wireless network planning in typical scenarios of ubiquitous power IoT. Telecommunications Science, 35:122-130.
[2] Zhang Y. (2017) Research on Intelligent Inspection System of Industrial Equipment Based on Internet of Things. Electronic Test, 23: 69 - 51.
[3] Wu S. (2017) Design and implementation of navigation module in intelligent inspection system. Beijing University of Posts and Telecommunications.
[4] Lin H, Liu Y, Zhao L, Wang X. (2019) Research on 230MHz Power Private wireless network Network Planning .Digital Communications World, 11: 63-64.
[5] Zhao X, Bai J, Ding G, Xiang L. (2019) Optimization of 230 MHz Power Wireless Communication Technology [J]. Telecommunications Science, 35 (09): 158-164.
[6] Chen X, Huang H, Fan X. (2020) Design of mobile terminal-based communication equipment and line inspection system. Computer Technology and Development, 01: 1-6.
[7] Zhou C, Zhou Z, Wang L, Feng X, Tang X. (2018) Design of LTE230 Digital Intermediate Frequency Transmitter. Electronic Design Engineering, 26 (06): 114-119.
[8] Yi P. (2019) Feasibility Analysis of Frequency Use of Discrete Carrier Aggregation Broadband System in the 223 ~ 235 MHz Band. Telecommunications Science, 35 (07): 109-114.