Research on Mobile Terminal Technology Supporting Intelligent Maintenance of Substation

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Abstract. In view of the fact that traditional substation maintenance operations need to carry a large amount of paper data and the on-site paperlessness is low, a mobile terminal supporting intelligent maintenance of substations has been developed. Introduce the development background, system integration scheme, various management functions of the device and its application in substation maintenance operations, recorder viewing and grid fault analysis. The application of the mobile terminal can improve the intelligence level and convenience of on-site maintenance operations, shorten maintenance time, improve maintenance quality, and improve the level of relay protection lean management.

1. Introduction

With the expansion of the power grid, a large number of substations have been put into operation, and the daily maintenance and maintenance tasks of the equipment in the station have increased significantly. Because the equipment is specialized and systematic, it is necessary to prepare a large amount of equipment information materials such as drawings and manuals for maintenance work. For the substation fault inspection, regular inspection, reconstruction and expansion of the new substation, the staff need to carry a large amount of paper materials such as standardized operation instructions, manuals, drawings, adjustment orders, test reports, etc. Insufficient paperlessness on site results in prolonged overhaul time and heavy workload.

This paper proposes a mobile terminal that supports intelligent maintenance of substations. It can obtain online standardized operation instructions, equipment instructions, site drawings, adjustment orders, historical defects, previous maintenance test reports and other materials from the relay protection mobile operation and maintenance data center. You can browse the protection function pressure plate, switch input and return information of the protection equipment in real time, historical self-diagnosis data, trip events and action waveforms. You can realize on-site paperless maintenance, and complete device value check, CRC version verification of SCD files in smart substations, automatic verification of virtual terminals and virtual circuits, etc. At the same time, the staff can record on-site defects online at the substation operation site, and the defect information can simultaneously complete the comprehensive comparison of on-site operating status information, picture information and video information. The application of this mobile terminal can improve the intelligence level and convenience of on-site maintenance operations, and enhance the level of lean management of relay protection.
2. System integration technology solution
During the application process, mobile devices need to pass verification and confirmation of operator qualifications and identities, connect to the communication network to connect to the big data platform client (i.e., relay protection mobile operation and maintenance data center), and receive technical support documents related to protection equipment through subscription mode.

2.1. Mobile terminal hardware and software
The mobile terminal needs to realize the mobile office function and related test operation functions of the substation. As shown in Figure 1: The hardware part mainly includes: Cortex-A7 dual-core processor, condition code/QR code scanner, RAM/FLASH, MICRO SD interface, lithium battery, capacitive touch screen, Beidou/GPS module, etc. The main frequency of the processor is 1.2GHz, which has strong processing and computing performance. Intelligent power management technology and equipment power consumption management function, can achieve 8 hours of continuous operation. Android 4.2.2 operating system can apply mainstream programming languages for software development. The touch screen is a 7-inch 1280 x 720 high-definition LCD display, 450 cd/m2 LED backlight, has an outstanding display effect in the sun. It is well adapted to outdoor operating environments. Because of multi-point capacitive touch screen, plus 4 function buttons, 1 special button for scanning code, 1 power backlight button, it is easy to realize human-computer interaction. It adopts Beidou/GPS automatic positioning, suitable for various applications of the Internet of Things. In addition, it has an IP65 protection level, waterproof and dustproof, a wide temperature operating range of -20~+60°C, and a humidity range of 5% to 95%, making it suitable for various extreme applications.

2.2. Mobile terminal access
The existing integrated data network at the substation side belongs to the safety zone III, so it is necessary to build a wireless access data network to access mobile terminals. The existing method is mainly based on wireless IEEE802.11 technology, which can meet the existing business requirements such as data collection and device control. The network structure can adopt the AC+FIT AP architecture. The security technology of wireless access can be combined with security technologies such as WPA2 AES encryption technology, TF card encryption technology. At the same time, the mobile terminal accesses the Zone III network through network security equipment such as firewalls, and all access processes need to pass the security isolation device. Also, wired access can be used when there is no wireless access condition.

In order to ensure the security of data interaction between the mobile terminal and the server, the mobile terminal transmits data with the server through the HTTPS transmission protocol. The mobile terminal and the server adopt an asymmetric encryption mechanism when using HTTPS for data transmission. The public and private keys are used to encrypt and decrypt the data. Any third-party malicious eavesdropper can only see the encryption content. The original data cannot be decrypted. In
order to ensure the legitimacy of the client, the mobile APP can also increase the authentication of the client digital certificate. The server will only establish a connection with the mobile APP after confirming that the digital certificate provided by the client is a valid data certificate stored on the server, otherwise the client will only get the error message that the connection failed.

In general, a mobile APP can use GET to establish an HTTPS connection with the J2EE server, submit query parameters, and wait for the server to return result data. If the mobile APP wants to submit data updates to the server, such as uploading a photo, you can use POST to transfer large-byte data.

3. Basic functions of mobile terminal
The mobile terminal should have the function of supporting professional data management to realize paperless work on site. The mobile terminal can receive the protection professional information pushed by the big data platform client. The maintenance personnel scan the unique codes of the corresponding field devices through the mobile terminal to retrieve equipment-related materials. Fill in and submit relevant records through the mobile terminal after the work is completed. Including defect records, maintenance records, and protection test records, you can upload them to the big data platform client.

3.1. Protection equipment ledger management
Protection equipment ledger management is to enter the ledger information of the protection equipment when the protection equipment is newly invested or modified, and establish the association of the equipment identification code and the equipment related information. Relevant account information needs to be updated in time after the replacement of protection equipment plug-ins, software upgrades or device retirement. The equipment account function meets the following requirements:

1) The equipment account information entry should support manual entry, automatic import of the factory information sheet provided by the manufacturer, and upload to the workstation after entry by the mobile terminal.

2) The equipment ledger information should include the board serial number, board model, board type/purpose, board hardware version, board number, board generation date and other information fields to facilitate board-level statistical analysis and management. At the same time, when the protection device plug-in is replaced due to defects or countermeasures, the device account information should be easily modified, and the historical replacement record of the board should be stored.

3) The identification code of the protection equipment can be associated with the equipment ledger, event, defect information, drawings, manuals, fixed value sheets, etc. At the same time, it supports two ways of association at the workstation and association through the mobile terminal. After the association, all the above information of the device can be found through the device identification code.

3.2. Professional inspection management of protection equipment
Protection equipment inspection management is mainly used for the generation and distribution of inspection task orders, work process control, and inspection record entry and upload. It has the following functions:

1) Establish a protective equipment inspection work instruction template according to the voltage level and equipment type.

2) Generation of inspection task list, including task name, inspection equipment, working hours, inspection route, person in charge, and work instructions for this inspection work, etc.

3) Issue the inspection task list to the person in charge of the work.

4) After work, upload the inspection record to the workstation through the mobile terminal.
3.3. Protection equipment inspection management
Protection equipment inspection management is mainly used for the generation and distribution of inspection task orders, work process control, and inspection record entry and upload. It has the following functions:

1) Establish a protective equipment inspection work instruction template according to the voltage level and equipment type.
2) Enter the safety measures for inspection of various types of protective equipment.
3) Generation of inspection task list, including task name, inspection equipment, working hours, person in charge, safety measures ticket, and work instructions for this inspection work, etc.
4) The inspection task list is issued to the person in charge of the work, and the approval and issuance process of safety measures and work instructions can be established as needed.
5) After work, upload the inspection records to the workstation through the mobile terminal.
6) The inspection report is automatically generated.

3.4. Protection equipment defect management
Protection equipment defect management is mainly used for the generation and distribution of defect elimination task orders, and the entry and upload of defect information, with the following functions:

1) Generation of a missing task list, including task name, defective equipment, working hours, and person in charge.
2) Issue the elimination task list to the person in charge of the work.
3) Upload the defect information to the workstation through the mobile terminal after work.

3.5. User Management
1) Various operations of users should be based on authority control.
2) The management system should support role-based permission settings.

4. Mobile terminal application
4.1. Routine maintenance work
We can use the mobile terminal to download the work task list from the workstation, while downloading the ledger, defect, event information of the related equipment, the drawings, technical specifications, fixed value sheets and other materials.

Before starting work, we use the mobile terminal to scan the electronic label pasted on the protection equipment, and send out an alarm when the work place is wrong. After the scan is correct, the device-related information can also be queried through the device identification code. At the beginning of the work, follow the pre-defined work procedures in the standardized work instructions, prompt the staff of the work content and technical requirements of each step, and fill in the required record information before proceeding to the next step. After the work is finished, the on-site work record information will be uploaded to the management system workstation through the mobile terminal.

The mobile terminal is compatible with the communication of the test terminal. It can realize the control and operation of the test terminal. The mobile terminal has special protection test modules such as distance protection setting check, zero sequence protection setting check, bus differential protection test, main transformer differential protection test, impedance characteristic test, etc. According to the MMS message to obtain the test result, it can realize the one-button test of the protection function.

4.2. Recording file viewing and grid fault analysis
The mobile terminal can automatically read power grid fault briefings and waveforms, and open waveform files in multiple formats (.cfg/.dat/.hdr). And you can choose to display the primary value or the secondary value according to your needs, and use the time scale to compare the effective values.
at the same time, and you can open multiple record files at the same time. When viewing recorded files, traditional PC-side recording analysis software generally provides scroll bars to facilitate users to scroll and view, but mobile applications are inconvenient to use scroll bars due to operational problems. At the same time, their applications are affected by the device screen size, processor performance and memory. The size limit requires the following optimizations in the information display and application process:

1) The recording file is simplified, especially the recording file generated by the fault recorder contains a large number of channels, but a fault actually only involves a few of these channels. Many other channels are not related to the fault, not only for analyzing the fault. Not helpful, it will also cause too many display channels in the fault analysis software, which will affect the efficiency of viewing and analysis. The simplification of the fault recording file is simplified from two perspectives: by analyzing the situation of each channel, it is determined whether it is a fault-related channel, if not, it is eliminated, and the fault recording file is simplified vertically by reducing the channels. By analyzing the failure time, only the data of several cycles before and after the failure time is intercepted, and other irrelevant data is deleted. The fault recording file is simplified horizontally by reducing the recording time.

2) Using page turning instead of scroll bars, mobile applications are not suitable for using scroll bars for extended viewing of pages. Generally, page turning is used instead, and a set of wave-recording browsing programs applied to mobile terminals have been developed based on mobile terminal usage habits. As shown in Figure 2:

![Fig. 2 Recording display map](image)

### 5. Conclusions

The mobile terminal that supports intelligent maintenance of substations is developed based on the Cortex-A7 dual-core processor hardware platform, and it has basic functions such as equipment ledger management, equipment professional inspection management, equipment inspection management, and defect management. It can quickly retrieve the required equipment-related technical data from the remote operation and maintenance center, which can be effectively used in daily maintenance operations, grid emergency repairs and grid failure analysis. It can improve the intelligence and convenience of on-site maintenance operations once and for all, and improve the level of lean management of relay protection.

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