Remote monitoring system design of power substation based on GPRS

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Abstract. This paper studies the design scheme of a substation remote monitoring system based on GPRS, and gives the solution about poor real-time and imperfect function of centralized substation monitoring system. The working principle diagram of the measurement and control device is introduced in detail, and the modules of analog acquisition and switching input are designed. The substation remote monitoring software based on GPRS communication is developed to realize the remote real-time monitoring of electrical and switching parameters and other functions, such as data query, fault early warning and energy efficiency analysis. The experimental results show that the system has the characteristics of real-time, multi-function and high reliability. It is of great significance to implement defensive maintenance, improve power supply quality, save energy and reduce consumption.

1. Introduction
In 1979, Japan developed the world’s first CNC system SDC-1 for distribution substations. The United States, Germany, France, Italy and other countries have successively developed their own products, such as the IMPac modular protection and control system developed by the United States and the substation integrated automation system LSA678 in xikouzi, Germany. Countries have made continuous breakthroughs in this field, and substation monitoring system has been widely used[1].

The research on Substation Monitoring Technology in China began in the 1980s. In recent years, with the rapid development of power system related technologies in China, ensuring the safe operation of power system has become the focus of relevant research. In case of sudden failure or temporary power failure in power system, it will bring huge economic losses and material impact to life and production. Therefore, at this stage, there is an urgent need for a technology to realize remote real-time monitoring of power system equipment[2].

Under the long-term sustainable development strategy, the related applications of power system restrict the rapid economic development. Accelerating the optimization of power system and improving the monitoring ability of power system equipment is the primary content of current research. The power system has many distribution transformer nodes, wide geographical coverage and extremely complex power grid lines. The power energy is transmitted from the power plant to the transmission line through the transformer and accepted by each power user through the step-down transformer. In this process,
there are many links that need the remote real-time monitoring system to monitor each node of the power equipment[3-4]. In the process of transmitting monitoring data, if wired communication is used, it will bring great working pressure to technicians and hardware laying personnel, so the wireless network technology for power equipment monitoring system is particularly important. At present, SDMs communication network and communication platform are widely used, but due to the limitation of data transmission mode, the system can not meet the use requirements when running[5-7]. Based on GPRS wireless communication network, this paper will design substation remote real-time monitoring system and deeply study the detection and maintenance of power system.

2. Overall design of substation remote monitoring system

Substation is an important node for power system control, regulation, protection and monitoring. The substation remote monitoring system uses advanced computer technology, modern electronic technology, communication technology and information processing technology to recombine and optimize the functions of substation secondary equipment (including relay protection, control, measurement, signal, fault recording, automatic device and telecontrol device), and monitor the operation of all substation equipment. Through the mutual exchange of information and data sharing among various equipment in the substation integrated automation system, the tasks of substation operation monitoring and control are completed.

The substation remote monitoring system replaces the conventional secondary equipment of the substation, simplifies the secondary wiring of the substation, and improves the safe and stable operation level of the substation. The integration of functions is the biggest feature of substation remote monitoring system. It is based on computer technology, data communication and information sharing.

The common substation remote monitoring system adopts the centralized control structure composed of front-end machine and background machine (general control unit). The front-end machine completes the functions of data input and output, protection, control and monitoring, and the background machine (general control unit) completes the functions of data processing and remote communication. The remote monitoring system in this paper adopts a hierarchical and distributed structure, as shown in Figure 1.

![Diagram](#)

Fig. 1 The dual configuration structure diagram

The two-layer distributed control system structure of whole station control level (station control level) and local unit control level (bay level) is set according to the control level and object of the substation. The equipment layer is the protection, measurement and control, safety automatic device and other secondary equipment with monitoring and acquisition function in the station. These equipment are
equipped with wireless network card. The secondary equipment of the equipment layer collects, stores and processes the primary and secondary information, sends it to the station control layer through the wireless base station in the substation, and can accept the control information of the station control layer. The station control layer generally includes integrated monitoring system, wave recording device, data network shutdown, synchronous clock, etc. The equipment in the station control layer is physically independent. Collect, process, store, display and forward the equipment information in the station through the wireless network, and operate and control the relevant equipment through the wireless network.

Dispatching centers at all levels collect substation operation information through telecontrol devices (data network shutdown), analyze and make decisions, and determine the economic and stable operation mode of power grid. As the external communication controller of the substation, the telecontrol device is an important part of the substation remote monitoring system. It creates a real-time database as the center of data processing to meet the real-time requirements of the dispatching master station. The telecontrol device communicates with the wireless terminal through the wired network and connects to the Internet network through the wireless terminal. A corresponding wireless terminal service device at the remote end receives the Internet network information and is connected to the remote monitoring system through the wired network.

3. Design of measurement and control device in equipment layer

In the substation, the status of primary equipment or other secondary equipment is collected through the secondary circuit, transmitted to the monitoring system in the substation through wireless communication, and received the control command of the monitoring system in the substation to control the primary equipment or other secondary equipment. As shown in Figure 2.

![Fig. 2 The dual configuration structure diagram](image)

See Table 1 for specific function configuration of measurement and control device.

| NO. | Function           | Explain                                                                                           |
|-----|--------------------|--------------------------------------------------------------------------------------------------|
| 1   | Telemetry          | Including voltage, current, power, frequency and direct flow processing                           |
| 2   | Remote signaling   | Including the processing of single point remote signaling and double point remote signaling      |
| 3   | remote control     | Processing including selective control and direct control                                         |
| 4   | Remote adjustment  | realising the acquisition and control of three groups of gears                                   |
| 5   | Communication      | Including communication with monitoring system and debugging software                            |
| 6   | Timing function    | Time synchronization modes such as B code, pulse or SNTP can be selected                          |
3.1. Design of analog acquisition module

The measurement and control device mainly completes the functions of analog quantity acquisition and switching value input and output. Analog quantity acquisition includes DC sampling and AC sampling. The schematic diagram of analog acquisition is shown in Figure 3.

![Fig. 3 Schematic diagram of analog acquisition](image)

The voltage and current signals obtained from voltage transformer Pt and current transformer CT cannot be directly input to CPU for data processing, but must go through signal conditioning circuit and A/D conversion circuit. Signal conditioning is to convert the U and I analog signals obtained from Pt and CT to the voltage range required by ADC through amplification circuit, low-pass filtering, sampling and holding. The A/D converter converts the analog quantity into digital quantity, and then transmits it to the CPU for calculation and processing of electrical parameters, so as to obtain various electrical parameters such as the effective value of u and I, active power, reactive power, power factor and harmonic.

3.2. Switching value I/O module

The function of the switching value input module is to realize the remote signal collection of the monitoring system in the substation, that is, by monitoring the auxiliary normally open and normally closed contacts of the switchgear in the substation, so as to identify the switching status of power devices such as load switch, circuit breaker, capacitor and transformer. Remote signal acquisition is vulnerable to electromagnetic interference, so low-pass filter circuit and photoelectric isolator are added to the switching value input module of measurement and control device. The switching value input through low-pass filter circuit and photoelectric isolator is shown in Figure 4.

![Fig. 4 Input diagram of switching value](image)

Chattering elimination shall be considered during switching value input. The software shall capture the first jump and start timing. When the delay time expires, it is still in the high-level state, and the displacement is effective. This event shall be officially recorded. Delay is generally taken as 5s.

The function of switching value output module is to realize the remote signal control of monitoring system in substation, that is, to control the opening and closing of power device switches in substation. In order to effectively resist interference, the switching value output signal adopts the export mode of "start + export" double command to further improve the reliability of switching value output. The device startup relay control circuit and outlet control circuit are shown in Figure 5 and Figure 6.
Fig. 5 Schematic diagram of starting control circuit

Fig. 6 Schematic diagram of outlet control circuit

The VCC in the figure is 3.3V. In the starting circuit, start is the control input of the starting relay from the CPLD (complex programmable logic device) chip of the CPU board. When "start" is low, the starting relay relay1 acts, the normally open contact is closed, and the starting +24V voltage rises to +24V. In the outlet circuit, out1 is the control input of 1 outlet relay, which is also from the CPLD chip of CPU board. When out1 is low level and +24V voltage is +24V, dout1 output drives the outlet relay corresponding to the outlet board to act, and the corresponding normally open contact is closed to control the outlet output.

3.3 GPRS communication module

GPRS wireless communication technology has the characteristics of high transmission rate, always online, low communication cost, convenient power supply and maintenance, wide coverage and so on[8-9]. The measurement and control device is connected with the main station of the monitoring system in the substation through an independent GPRS link. The GPRS module of the measurement and control device adopts the square M590 GPRS module. After the measurement and control device establishes a point-to-point protocol (PPP) link with the operator through the M590 GPRS module, it uses the at command at+tcpsetup = < n >, < IP >, < port > to establish a GPRS link with the master station of the monitoring system in the substation, where n is the link number, which can only be 0, 1, 2, 3, and IP is the address of the master station of the monitoring system in the substation to be linked, Port is the port number provided by the main station of the monitoring system in the substation. After the GPRS link between the measurement and control device and the main station of the monitoring system in the substation is established successfully, the measurement and control device can communicate with the main station of the monitoring system in the substation. The GPRS link establishment process is shown in Figure 7.
4. Software and hardware design of integrated monitoring system

The networking mode of the monitoring system is distributed, and all servers can be deployed. Even if the equipment manufacturers are different, as long as they are in the same region and on the same platform, the system can realize unified management, and the platforms do not affect each other. Each platform manages itself, and the overall operation of the platform will not be affected by a single point of failure. In any platform, there is its own management system. Like the control protocol, this system is unified, which can authorize users in this range, and the resources between them can be shared, which is also to ensure the interoperability of resources in the whole network. For the operation status and performance status of the primary and secondary equipment in the substation, the monitoring system can make the personnel on duty clear at a glance, which has been optimized in terms of equipment maintenance, labor intensity and man hour cost, so as to ensure the safe and reliable normal operation of the power system.

The hardware of the monitoring host adopts the server, which runs the integrated monitoring system software, can communicate with the Bay layer and other station control layer equipment, and realize the functions of analyzing, displaying and storing real-time communication data. The basic functions of the integrated monitoring system are as follows:

4.1 Data acquisition, processing and storage

4.1.1. Analog quantity includes electric quantity such as current, voltage, active power, reactive power, frequency and power factor, and non electric quantity such as temperature.
4.1.2 Switching value acquisition includes position signals of circuit breaker, disconnector and grounding knife switch, protection action signals, operation monitoring signals and tap position signals of on load voltage regulating transformer, and realizes functions such as timing acquisition, equipment abnormal alarm, event sequence record (SOE), operation record, logic operation, etc.

4.2 Alarm processing

4.2.1. In the stage of the first accident alarm, if the second alarm occurs, it can be handled in the same way, and the first alarm will not be overwritten.

4.2.2. In case of advance alarm, except that the processing method is the same as that of accident alarm, the sound and information color can be different from accident alarm, and can selectively send information to the distance.

4.3 Control operation

4.3.1. With local / bay level / station control level / remote, multi-level control, with necessary safety inspection and error proof locking, to complete the control of switch and knife switch; Adjustment of tap of main transformer; On / off of protection function pressing plate; Control functions such as signal reset and equipment start and stop.

4.3.2. The monitoring system provides two anti error locking functions at the station control layer. One is to cooperate with the special microcomputer anti error system to complete the anti error locking function of the whole station; The other is the software anti error locking function embedded in the system. The user can complete the design of station control layer locking logic through a friendly software locking logic definition tool. The two functions can be used together to complete the anti error locking of station control layer.

4.3.3. The monitoring system has the operation monitoring function, allowing the operator to work in one workstation, and the supervisor can monitor on another workstation; When one workstation fails, the operator and supervisor can operate and monitor on the same workstation. In order to prevent misoperation, step-by-step operation is adopted under any control mode, i.e. selection, calibration and execution, and operator and supervisor passwords and line codes are set at the station level to ensure the safety and correctness of operation.

4.4 Interface

It can monitor the operation parameters and equipment status of main electrical equipment through the display. The screen supports double screen display, and the screen operation supports stepless zoom. It can roam smoothly and has the function of guide map. The main display screen includes:

4.4.1. Main electrical wiring diagram, including real-time values showing equipment operation status, power flow direction, main electrical quantities (current, voltage, frequency, active power, reactive power), etc.

4.4.2. Operation diagram of computer monitoring system: display the equipment configuration and connection status of computer monitoring system in graphic mode and color change.

4.4.3. Configuration diagram of secondary protection, reflecting the switching condition and setting value of each set of protection.
5. Conclusion
In general, the GPRS based remote monitoring system developed in this paper has high real-time performance, comprehensive functions, superior performance and stable operation. It is of great significance to implement defensive maintenance, improve power supply quality and save energy and consumption. This design idea of applying wireless communication mode to substation remote monitoring system is the innovation of this paper.

Acknowledgments
Under the careful guidance of Deng Maojun and Niu Zhilei, I successfully completed the compilation, revision and finalization of this paper. Thank you two mentors, my parents and my friends. You are my strong backing.

References
[1] Ding Shuwen, Huang Xuncheng, Hu Qizhou. Principle and application of substation integrated automation [M]. First edition. Beijing: China power for publishing, 2003: 27-28.
[2] Peng Zhiqiang, Zhang Qibing, Su Dawei, etc. Remote operation and maintenance technology of substation monitoring system based on GSP [J]. Power automation equipment, 2019, 39 (4): 210-216.
[3] Xiang Chunzhi, Lv Shulin. Remote monitoring system for ship operation status under wireless network [J]. Ship science and technology, 2017, 39 (18): 73-75.
[4] Cuiyu, Wu Yi, Zhang Zhi, etc. Design and implementation of relay protection intelligent mobile operation and maintenance system based on power wireless virtual private network [J]. Power system protection and control, 2018, 46 (23): 175-181.
[5] Xu Xinqian, Xulai, Chenjie, etc. Cable channel emergency monitoring system based on mobile wireless sensor network [J]. China power, 2020, 53 (1): 66-71 + 99.
[6] Xiong Haijun, Zhanghai. Research on wireless network structure design strategy of power equipment monitoring system [J]. Electrical measurement and instrumentation, 2020, 57 (21): 24-31.
[7] Yu Jinhui, Zheng Xiaoyi, Zhao Shiyan, etc. Development of remote monitoring system for port mechanical equipment based on WLAN [J]. Mechanical design and manufacturing, 2018 (4): 269-272.
[8] Guo Yaohua. Wireless temperature monitoring system of intelligent substation equipment based on ZigBee and GPRS network [J]. Electrical technology, 2016, 11(A): 44-45. Instrument technology and sensors, 2014 (1): 79-82.
[9] He Biyi, Zhou Guoping, Ding Jianqiang, etc. Design of a monitoring system for box type substation based on WSN and GPRS [J]. Electrical technology, 2016, 11(A): 44-45.