Design of intelligent detection system for high voltage circuit breaker based on functional integration

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Abstract. Since there are various preventive test items for high voltage circuit breaker, in this paper, a function-integrated hardware is put forward to reduce the height and wiring times of the test personnel and improve the field work efficiency. Firstly, we comprehensively analyze the electrical test requirements for high voltage circuit breaker. Then we integrate multiple detection projects into one system, taking advantage of the fact that each test project can be merged. These test projects include tests of dielectric loss of circuit breaker, capacitance value, circuit resistance, direct resistance of switching coil, mechanical characteristic, closing resistance and closing time as well as insulation resistance and AC withstand voltage of auxiliary control circuit. Next, we configure the required detection items and relevant parameters before the test. Finally, we complete the whole process, which requires connection and disconnection for only once and will automatically finish all project detection, test data collection and intelligent analysis item by item.

1. Introduction

High voltage circuit breaker is the core equipment for controlling and protecting the circuit in the primary power system. It is of great significance for the safe and reliable operation of the power grid to find out the potential fault of high voltage circuit breaker in time and avoid unexpected accidents. With the higher requirements of the pre-test regulations and the stricter requirements of various countermeasures documents, more and more problems are encountered in the test of high voltage circuit breakers, especially in the case of 500 kV circuit breakers. Firstly, there are many testing items for 500 kV circuit breaker, and many kinds of instruments are needed to carry out the test. Frequently handling and changing instruments, changing test leads and connecting and removing wires, and using different testing instruments and software require high labor intensity, therefore having high requirements for the test personnel. Secondly, manual management of each test result requires a large amount of paper records, which is prone to cause waste of resources and data loss when archiving and filing. Finally, the test results need to be judged manually, and the field test personnel are prone to make mistakes due to fatigue and negligence, resulting in the misjudgment of the test results.

In order to reduce the risk of field test operation and improve work efficiency, in the case that the research and development conditions of materials, structure and hardware are mature, it is necessary to develop an intelligent test system which integrates various test projects in view of the current problems in the electrical detection of high-voltage circuit breakers.

2. Current deficiencies

According to the “Regulations for Maintenance Test of Southern China Power Grid”, the current routine preventive test items for high voltage circuit breakers mainly include mechanical
characteristics, insulation resistance, circuit resistance, dielectric loss and capacitance of voltage equalizing capacitors, etc. The implementation of these testing projects is not only time-consuming and laborious, but also has certain operational risks. In addition, the requirements for test leads vary widely among many test items of the high-voltage circuit breaker. Some test items require the test leads to be able to withstand high voltage and have double shielding properties, such as dielectric loss and insulation resistance items. Some items require the test leads to be able to withstand large current, such as the loop resistance item. At present, the intuitive and mechanical method is to connect 1-2 leads which can meet the needs of high voltage and high current detection at each terminal, so more lead wires and wiring times are required. When detecting a different test item, the high voltage circuit breaker needs to be reconnected.

According to the field test work analysis, there are three main problems in the current electrical test of circuit breaker:

Firstly, the workload is large and the work efficiency is not high. Using conventional instruments for testing requires configuring multiple instruments and replacing test wiring and instrument operation. And with the increase in the height of the ports of the high voltage circuit breaker, frequent disconnection brings a lot of work intensity.

Secondly, the security is low. More wiring times not only make the wiring personnel face more risks brought by inductive electricity, but also increase the possibility that the breaker bushing is damaged in the wiring process.

Thirdly, the measurement accuracy is not enough. Due to the limitations of the on-site inspection environment and conditions, the measuring instruments will be affected by the field interference during the measurement process, so requirements for the properties of instruments are high.

3. Design of detection system
The conventional preventive test items for high-voltage circuit breakers mainly include: mechanical characteristics, insulation resistance, loop resistance, dielectric loss and capacitance of the equalizing capacitor, etc. These test items have different requirements for the voltage and current during the test, as shown in figure 1: the circuit resistance test requires that the current end output 100A dc and that the voltage be low; the dielectric loss test requires that the 10kV ac high voltage be output; the insulation resistance test requires that 1kV DC high voltage be output; and mechanical characteristic test requires the output of 220V/110V DC low voltage and 10A current.

![Diagram of test requirements for each test item](image-url)

Figure 1. Test requirements for each test item

In this paper, the requirements for various electrical tests of high voltage circuit breaker, such as AC, DC, high voltage and high current, etc, are comprehensively analyzed at first. Then, in view of the problem that test methods among projects vary largely, the test part and power part of each test item are reasonably merged. Then the configuration of function modules of the four detection functions, namely, mechanical characteristics, circuit resistance, insulation resistance, dielectric loss and capacitance, is optimized, and through reasonable layout and isolation of high and low voltage equipment, the volume and weight of the instrument are reduced. Finally, the routine preventive test items of the high voltage circuit breaker are integrated into a set of system through function integration.
Before the test, only required test items and related parameters need to be configured, so that the whole process of wiring and disconnection can be realized, and all project inspection, test data collection and intelligent analysis can be completed automatically.

The system structure is shown in Fig. 2. The system is mainly composed of lead, intelligent wiring unit, system host and PC. The PC is connected to the system host through optical fiber, and system parameters and operation tasks can be set in the software interface. After receiving the command from the PC, according to the preset test items and sequence, the system host automatically controls the intelligent wiring unit to switch internal wiring according to different test items, so as to realize the integration, switching and insulation isolation of the lead of each test item, and then to carry out a series of tests.

**Figure 2** System structure diagram of functional integration

Compared with existing technology, the intelligent detection system of high-voltage circuit breaker based on function integration designed in this paper integrates the routine preventive test items of high-voltage circuit breaker into a whole, and automatically controls the automatic switching of the wiring of the intelligent wiring unit through the control command of the PC. The automatic detection of all test items is completed after one connection, which reduces the labor intensity and requirements for the test personnel, improves the work efficiency of the test, reduces the power outage time, and makes the test of the high voltage circuit breaker more reliable.

### 4. Components

#### 4.1 Design of PC

The PC mainly contains centralized control software, which is the control core of intelligent detection system for high voltage circuit breaker. It consists of four parts, namely, the login unit, the process control unit, the data processing unit and the auxiliary function unit. The login unit includes the manager module and the tester module. The process control unit includes the scheme management module, the operation control module, the data processing module and the background data forming module. The data processing unit includes the data query module, the data marking and archiving module, the data and atlas comparison module and the database management module. The auxiliary function unit includes the procedure inquiry module and the report generation module. The centralized control software mainly realizes test parameter configuration, device automatic control, data analysis and management, test report output and other functions. It uses Visual Studio to develop the program and MySQL to process the database, which facilitates the experimenters to retrieve and search test data.
4.2 Design of system host
The system host is mainly composed of the power supply module, the control module, the communication module, the measurement module and sensors of each detection item. The structure of the system host is shown in Figure 4. The power supply module includes the high-voltage power supply module and the low-voltage power supply module, which are connected with the intelligent wiring unit through the test power supply line and the low-voltage connection line respectively and provide the high-voltage power supply and the low-voltage power supply respectively for each detection item of the high-voltage circuit breaker. The control module is connected to the opening and closing coil of the circuit breaker through the control loop, and is mainly used to control the opening and closing of the circuit breaker during the test. The communication module communicates with the PC and the intelligent wiring unit through RS232, receiving the command of system host and sending the command to intelligent wiring unit, and transmits the detection data collected by the sensor. Measurement module connects with the sensors of various detection items installed at the corresponding position of high voltage circuit breaker through the test line, and is used to acquire the detection data collected by the sensors of corresponding detection items, and conduct data classification.

4.3 Design of intelligent wiring unit
The intelligent wiring unit is mainly composed of high and low voltage switching devices. It realizes the integration, switching and insulation isolation of the lead wires of various detection items, and there are five states: high-voltage, low-voltage, short-circuit, grounding and suspension. Taking phase A of high voltage circuit breaker as an example, when the dielectric loss is measured, A1 and A2 are in low voltage state, and 10kV high voltage is added at the COM end. When the loop resistance is measured, 100 A current is added between A1 and A2, which are in low voltage state, and the COM terminal is in the suspended state. When mechanical properties are measured, A1, A2 and COM are all
in low-pressure state.

Pertinent structure design is put forward in this paper to meet special switching requirements such as large current, high voltage and so on. Figure 5 shows the structure of high-voltage switching unit, which issues commands to the actuator through the centralized control software and connects the corresponding circuit to the lead terminal to achieve the purpose that no line needs to be changed.

![Figure 5 Structure diagram of high voltage switching unit](image)

4.4 Design of leads

The lead part includes special fixture, main lead and circuit breaker control line. As shown in Figure 4, there are 9 main leads in the system. Similarly, taking phase A of high voltage circuit breaker as an example. The main leads of two common ends (COM) are composed of core wires, internal shielding, external shielding and main insulation, and the insulation strength of the main insulation layer is 12 kV, the rated current capacity is 1A, and the diameter of the line is less than 10 mm. The main leads of ports (A1, A2) are composed of core wires, internal shielding, external shielding and main insulation, and the insulation strength of the main insulation layer is 3kV, the short-term current capacity is 100 A, and the diameter of the line is less than 15 mm. The structure design of high voltage and low voltage output leads is shown in Figure 6.

In this paper, in view of dielectric loss test and insulation resistance test, the two high voltage test projects, high-intensity insulation materials and shielding measures are used to isolate the high-voltage output channel from the power supply part in order to make the system more compact.

![Figure 6 Structure diagram of high voltage and low voltage output lines](image)

4.5 Standard interface design for secondary lead wires

A large number of secondary terminals are involved when the high voltage circuit breaker is under various test projects, especially during the insulation and withstand voltage test of auxiliary and control circuit. Through combing and merging the secondary terminals involved in various projects, in this paper we have designed the standard interface of secondary lead which meets the requirements of insulation and AC withstand voltage. As shown in Figure 7, through the switching and output of AC and DC, the function of wiring can be completed in the field inspection only by inserting the aviation plug into the base of the control cabinet. And when the same test item is performed again, the connection between the base and the functional terminal is not required, and only the connection
between the aviation plug and the base needs to be completed, which avoids the loosening of the terminal caused by re-wiring in each test project, reduces the wiring error rate and improves the work efficiency of the experimenters.

Figure 7 Design diagram of standard interface for secondary lead wires

5. Conclusion
The intelligent detection system of high-voltage circuit breaker designed in this paper can complete various test projects, such as test of mechanical properties of high voltage circuit breaker, loop resistance test, insulation resistance test, dielectric loss and capacitance test, through one-time wiring and disconnection, which is attributed to the design of software control, intelligent wiring unit, double wiring structure and standard interface of secondary wiring. The design in this paper reduces the workload on site, reduces the safety risks of testers, improves work efficiency, and ensures the safe operation of the substation.

References
[1] Guozheng Xu, Jierong Zhang, Jiali Qian, etc. Principle and Application of High Voltage Circuit Breaker [M]. Beijing. Tsinghua University Press, 2000.
[2] Quanzhi Liu, Mingyi Shi, Hong Qin. On-line State Detection and Diagnosis Technology for High Voltage Circuit Breakers [J]. High Voltage Technology, 2001, 27(5): 29~31.
[3] Yizhuang Huang. Substation Integrated Automation Technology [M]. Beijing. China Power Press, 2000.
[4] Kexing Fang. Breaker Fault and Monitoring [M]. Beijing. China Power Press, 2003.
[5] Shaohua Wang, Ziqiang Ye, Bingxiao Mei, etc. Application Status of On-line Monitoring and Live Detection Technology for Transmission and Distribution Equipment in Power Grid [J]. High Voltage Apparatus, 2007, 43(2): 133~135.
[6] Guang Chang. Research on Vibration Monitoring and Fault Diagnosis of High Voltage Circuit Breaker [D]. Beijing Jiaotong University, 2013.
[7] Jing Zhang, Shaoqiang Liu. Detection Technology and System Design [M]. Beijing. China Power Press, 2001.
[8] (Bosnia and Herzegovina) Captanovic. Theory, Design and Test Method of High Voltage Circuit Breaker[M]. Beijing. Machinery Industry Press, 2015.