Distribution terminal automatic test system based on portable solution

Liang Weichen¹, Liu Bo¹, Liu Junna¹, Li Xuan¹ and Xiao Lin²

¹ North China Electric Power Research Institute Co., Ltd, Beijing, China
² CYG Sunri Co., Ltd, Guangdong, China
E-mail: liangweichenheng@163.com

Abstract. Distribution terminals have been widely and maturely applied in China currently. However, due to the large number of manufacturers, the differences in production technology, research and development technology lead to inevitable differences in the quality stability of distribution terminals. At the same time, it is also necessary to locate the faults of distribution terminals that are operating online and have faults. The traditional manual test method is difficult to meet the requirements of test specifications. It is also necessary to consider the requirements for testing batch operations and multi-scene applications. Based on the background, this paper proposes a distribution terminal automatic test system based on portable solution, which can complete the automatic test for distribution terminal in multiple scenarios.

1. Introduction

The distribution automation system is the core of distribution automation. It realizes the monitoring and control of distribution network system by comprehensively utilizing multiple communication methods [1]. Distribution automation helps improve the reliability of power supply and power quality, and reduce operation costs. A typical distribution automation system usually consists of a distribution master station, distribution terminals, distribution stations and communication channels. Distribution terminal is an important part of the distribution automation system, as the basis of the whole system, the integrity and reliability of its function is the prerequisite and guarantee for the normal operation of the system [2] [3]. At present, the State Grid requires that the distribution terminals pass the full or sampling inspection at each provincial electric power institute before they are put into use on the site, and they should strictly meet the requirements of the inspection specifications [4] is necessary to confirm the function and performance of the distribution terminals provided by different suppliers to ensure the same the consistency and quality reliability. At the same time, stable and reliable test tool is also required for the maintenance of the distribution terminals in the field operation and the problem location of the distribution terminals with the existing failure.

According to the specific requirements of the test, in the normal manual test mode, the tester needs a series of instruments and equipment, and it is difficult to match the test specification requirement, and the test operation process of many items is cumbersome and difficult to implement [5] [6] For example, the basic error test of telemetry needs to provide a wide output range and high-precision source, and because the distribution terminal has no display screen, so the actual collected AC volume needs to be established after it is connected by the remote desktop. This method has too much impact on test efficiency. And for tests similar to telecommunicating anti-shaking, it is hard to control the time delay of the ms level, so the test items are hard to be tested accurately.
Research and develop a portable distribution terminal automation test system for practical application needs. It can be applied to batch testing by integrating multiple sets of portable power distribution terminal automatic test systems with the cooperation of load simulation devices, wave recording devices, switches and other equipment. It can simultaneously support automated testing of multiple power distribution terminals and simultaneously output test reports. In the application scenario of maintenance and small batch fault location, it can also realize the automatic test of most functions.

2. Overall system design
According to the requirements of the State Grid for the test of distribution terminals, the inspection is refined to the appearance and structure inspection, interface inspection, main function test, wave recording function test, basic performance test, wave recording performance test, telecommunicating anti-shaking test, timing test, insulation performance test, power supply test, communication test, etc [7]. In order to realize all the test functions, it is necessary to integrate a high-precision, wide-range output range of program-controlled AC standard source module, input-output module, timing module, program-controlled AC and DC source module, fault recording module, external interface module and other functional components and QR code scanner.

In order to balance the application in laboratory and on-site application environment, the test system is designed based on portability solution which is in control of volume and weight. Because of such considerations, the system integrates the industrial computer, the display module, the AC standard source module, the input-output function module, the timing module and the program-controlled AC and DC source module.

The distribution terminal is usually divided into two specifications: 1A and 5A. The accuracy level of the voltage and current is 0.5, and the current impact test of 10 times and 20 times is required, and it corresponds to 4U, 4I input test requirements. So design the AC standard source module to achieve 0-450V voltage, 0-100A current output, while the output voltage accuracy level is 0.1, when the current does not exceed 20A, its preparation level is 0.1, and the preparation level is 0.2 when the output range is 20-100A, and it can output 4U, 4I at the same time. The input-output module adopts a passive design, which establishes a connection with the hard contacts of the distribution terminal, and then implements automatic testing of the switching quantities through software matching. As the time acquisition requirements for the switching quantity are strict during the test, it is necessary to achieve extremely low opening delay. The timing module can accept GPS and Beidou satellite signal to ensure the synchronization of the various functional components of the test system, at the same time, it can output accurate timing signal through IRIG-B code, 1 PPM/1PPS/1PPH(TTL) and other pulses. The program-controlled power module can output the set AC and DC voltages in time series under the control of the host computer to match the objective test conditions of the power switching test.

![Diagram](image)

**Figure 1.** Portable distribution terminal test system block diagram.

The test system integrates the main functional modules, and its industrial computer installs and runs the test software. The software establishes a connection with the distribution terminal through the function of the main station, and it can control the distribution terminal and exchange information with it. The specific output and collection functions are completed by controlling the integrated function
modules, and the distribution terminal can be tested in turn. Depending on the configuration of the test system, each test system can correspond to an automated test of distribution terminal. Its system structure block diagram can be as shown in Figure 1.

As shown in the above figure, the test system can be directly applied to the basic test of a single distribution terminal. However, due to the portability requirements, the system does not integrate the load simulation function component and the wave recording function component, so that the actual reference recording in the power performance test and the wave recording performance test has consistency in consistency with the expected waveform, therefore, in the laboratory scenario, load simulation device and wave recording device need to be added to make up for the defects here. In the laboratory scenario, due to the demand for batch testing, multiple sets of portable distribution terminal test systems can be networked, and the test system software runs from the server of the laboratory. The terminal, under the condition of correct wiring, completes the automated test of batching according to the setting of the existing test cases of the system.

Due to the high performance requirements, the above components and functions need to be developed and implemented. And the simulation of the fault scene waveform is difficult to achieve through the timing addition method, so the fault waveform playback is also the focus of research.

3. Implementation of automatic test function components

Analysis from the principle, the test procedure can be summarized as applying basic external conditions required for a certain type of test to the distribution terminal, and then analysing information such as telemetry, remote signal, SOE, and wave recording files generated by the terminal in response to the condition, this is a criterion for compliance with the requirements of the specification.

Considering the needs of the State Grid for the test and the existing mature solutions in the market, some functional modules such as timing module, programmable power module can use mature solutions already on the market, and the specific function can be achieved by structurally designed and installed and control matching of the software. The AC standard source module design achieves 0.1% high precision under normal working conditions of the distribution terminal, so as to meet the requirement that the test standard source is at least 5 times higher than the tested equipment, and for the 10 times and 20 times current impact test scenarios, its accuracy can be relaxed to 0.2%. Due to power consumption considerations, 10 times and 20 times currents are only allowed for short-time loading, and the system will be protected from exiting when timeout.

The program-controlled input-output module is based on a mature and stable CPU+FPGA+CPLD architecture and runs the VxWorks real-time operating system to ensure excellent industrial-grade real-time performance. The output signal needs to maintain the delay accuracy of less than 200us, the operation time of the traditional mechanical relay cannot meet the test of the distribution terminal. Therefore, the method of driving optical coupling relays by CPLD is realized. Its architecture is shown in Figure 2 below.

![Figure 2. Program-control input-output module hardware architecture block diagram.](image-url)
4. Waveform playback function implementation

The distribution terminal stores the recorded wave files in a format defined by the Comtrade 1999 standard. The recorded wave file usually records not less than 4 cycles before the occurrence of the fault and not less than 8 peripheral waveform data after the occurrence of the fault. Recording files are stored in CFG configuration files in ASCII text and DAT data files in binary format. The configuration files contain channel information such as sampling speed and number of channels, and the data file contains each sampling channel and its corresponding sampling value.

In the application of the system, the programmable AC standard source module reconstructs and outputs the fault waveform characterized by the data analyzed from the waveform file data, and then the system acquires and compares the waveform recorded by the fault recorder under the condition of the recording starting condition. The system collects the actual action information of the distribution terminal, and compares it with the expected state, thereby completing the evaluation of the function and performance.

In essence, the waveform file records a series of discrete points in the time domain. Waveform playback is to reduce the discrete points into continuous waveform by fitting and modeling. Generally, when the sampling rate standing for discrete time-domain interval is higher, the waveform that is directly point is closer to the continuous analog signal recorded by the waveform files. In practical applications, waveform files usually record data at a sampling rate up to 10ksps, but in order to maximize the representation of the continuous signal represented, the system uses the interpolation algorithm to establish a mathematical simulation, simulates the sampling rate of 100ksps and above, and uses it as the basis of the inversion waveform to maximize the approximation of the actual recorded waveform.

For the interpolation of consecutive discrete sampling points in the time domain, if the sampling interval is small, an interpolation algorithm with equal three-point interpolation can be used. Let N be the sampling interval, A(T0) be the sampling value at time T0, A(T1) be the sampling value at time T1, A(T2) be the sampling value at time T2, and A(Ts) be the sampling value at time Ts, the interpolation time Ts is within the effective latching range of the three time points T0, T1, T2, then A(Ts) can be calculated by the following formula 1.

$$A(Ts) = A(T0) + \left( A(T1) - A(T0) \right) \cdot \frac{Ts - T0}{N} + \left( A(T2) - 2 \cdot (Ts - T0) \right) \cdot \frac{Ts - T1}{2 \cdot N} \tag{1}$$

If the sampling interval of the sampling points is large, it can be realized by a line one-time interpolation algorithm. That is: when A(T1) is the sampling value corresponding to T1, A(T2) is the sampling value corresponding to T2, and Ts is the sampling time within the range of T1 and T2, then the sampling value corresponding to Ts can be obtained by formula 2 shown below:

$$A(Ts) = A(T1) + \left( T2 - T1 \right) \cdot \frac{A(T2) - A(T1)}{(T2 - T1)} \tag{2}$$

After the waveform is reconstructed by the interpolation algorithm, the programmable AC standard source module outputs the reconstructed waveform according to a strict definition to complete the subsequent test.

The waveform library pre-stores the operational status of the various types of faults that characterize the actual distribution terminal or the operational status required to characterize a steady-state test item. The waveform inventory is located under a specific path folder, the software reads the specific waveform file under the path, and parses the waveform file, establishes a mathematical simulation by the application of the interpolation algorithm, restores the analog signal recorded by the waveform file, and then controls the waveform the AC standard source module output matching the waveform file. According to this, the transient characteristics of the operating state such as the fault state of the simulated distribution network can be realized, and the mode can also test the characteristics of the distribution terminal in other working states.

The high precision of the wave recorder makes it a property of the comparison benchmark. By reading the fault recording recorded by the distribution terminal and automatically comparing it with the waveform recorded by the wave recorder, the recording function and the recording performance of the distribution terminal to be tested can be judged.
The control flow of waveform playback is shown in Figure 3 below.

![Figure 3](image)

**Figure 3.** Summary flow of waveform playback.

5. **System software function**

The design of system software follows the principles of scalable, traceable and easy-using, the basic architectural block diagram is shown in Figure 4 below.

![Figure 4](image)

**Figure 4.** System software function block diagram.
The test case contains the required test sequence of the sequence of AC volume, the sequence of switches, and so on. It shows a particular test item, and the expected response of the distribution terminal under this condition. The software completes the test of the item by comparing the signal of the remote signal, telemetry, SOE and other signal outputted by the distribution terminal in response to the actual excitation condition with the expected response. For the actual operator, the test case is the most basic tool and means of the testing. Standard test cases and test tasks are stored in the database, so that standard test cases and modified test cases can be saved, and it can be transplanted.

In the human-computer interaction interface and the advanced application function module, the user management can set the specified test system user and perform the necessary authority management. The advanced functions include functions such as reading and setting parameters of the distribution terminal, reading of the recorded files, and reading and judging the two-dimensional code information. The automatic test control module is the core control centre of the test system software, its function is including test environment construction, test task control, test status monitoring and test report generation. The test report takes the test results saved for each test item and outputs the test report according to the specific format requirements [8].

The principle and execution process of the test cases of different test items are similar, taking the terminal current and voltage acquisition accuracy test as an example: the test case sets the addition sequence of the AC standard source, and sets the amount of remote communication and the allowable error range that the terminal will send in the expected time. After the test is started, the software controls the AC standard source to output the current and voltage according to the time, amplitude and phase set by the sequence. At the same time, the software monitors and acquires the action of the telemetry information sent up by distribution terminal. The expected results are compared to make an automatic judgment. The test results and test procedures are stored in the database and displayed in the test report.

6. Practical application effect

The portable power distribution terminal detection system studied in this paper is suitable for on-site and small-scale maintenance. And it is suitable for large-scale testing in the laboratory environment. The system has the advantages of simple configuration and operation, which can reduce the requirements for actual operators. At the same time, the rigorous testing principle and testing process ensure the reliability of the test. The detection system has full automatic test function which could effectively improve the testing efficiency. It has great significance for the full inspection, sampling inspection, on-site maintenance and fault location of the distribution terminal, and has broad promotion space and application prospects.

7. References

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