Application of Arrester Simulation Device in Training

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Abstract. Combining with the arrester simulation device put into use successfully, this paper introduces the application of arrester test in the insulation resistance measurement, counter test, Leakage current test under DC 1mA voltage and leakage current test under 0.75U1mA. By comparing with the existing training, this paper summarizes the arrester simulation device’s outstanding advantages including real time monitoring, multi-type fault data analysis and acousto-optic simulation. It effectively solves the contradiction between authenticity and safety in the existing test training, and provides a reference for further training.

1. Introduction
The operating electrical appliances in the electrical power system switching overvoltage not only withstand the power-frequency voltage in normal operations, but also are affected by the temporary overvoltage, switching overvoltage and lightning overvoltage. Under the impact of overvoltage, the device insulation may be damaged or even result in accidents. Therefore, a series of measures must be taken to limit the overvoltage in the electrical power system, and the arrester is one of the important overvoltage protection measures in the electrical power system.

As the important overvoltage protective device in the electrical power system, the arrester's reliable operation is of vital importance for power equipment or even the entire high-voltage system. However, the arrester's overall performance gradually decreases due to moist, aging, long term operation under the working voltage, and the impact of various kinds of overvoltage, etc., which results in various kinds of failure⁴. These problems can all be detected by tests, so as to prevent the arrester from causing accidents such as maloperations or even explosions. The testing skills of arrester testers directly concern the accuracy of test data and conclusions. Therefore, training for relevant personnel on their professional competence in testing is particularly important.

However, how to improve the arrester testing is still in the stage of theoretical lecturing and spot demonstration, and there is the lack of systematic and professional skill training measures. Electric power training institutions have actively carried out training on arrester testing in recent years, but such tests are mostly electrified tests in real devices, which can not safeguard the personal safety of inexperienced trainees under high voltage. Meanwhile, due to the lack of the supporting simulation control system, it is difficult to monitor trainees' operations in a real-time manner and the test results are single, which makes it impossible to improve trainees' ability to analyze multi-type failures of devices.

In the face of the sharp contradictions between keeping the site real and keeping operators and devices safe, this article introduces a method that reconstructs the arrester which is the tested object. By following the concept of "replacing high voltage with signals", it fundamentally solves this problem in training. Meanwhile, a systematic and professional simulation system is built with the help
of the teacher guidance platform to monitor trainees' test conditions in a real-time manner, and multi-type failure results are preset, which effectively improves trainees' data analysis ability.

2. **Composition of arrester simulation device**

Featuring such advantages as quick actions, flat volt-ampere, low residual voltage, big through-flow capacity, stable performance and long life, the zinc oxide arrester has become the most widely used arrester at present \[^{[2,3]}\]. Therefore, the arrester simulation device involved herein is designed and made for the zinc oxide arrester. The simulation arrester employs the appearance design as well as the terminal and identification which are basically the same as those of the actual device in the power grid. Its interior is made up of four modules, namely test control, wiring test, acousto-optic simulation, and wireless communication. Figure 1 shows the arrester simulation device.

![Figure 1. Arrester Simulation Device](image)

Test control module: The test control module is the control center of the entire arrester simulation device. It analyzes the commands from the teacher device, then controls the implementation by each module. It collects the data of the wiring test module, acousto-optic simulation module and wireless communication module, feeds them back to the teacher device, presets the test results, and meanwhile monitors the test instrument's display interface, operating state and wiring state in a real-time manner.

Wiring test module: It tests the wiring, collects signals that show whether the test instrument parameters set are correct, and transmits the results to the test control module.

The acousto-optic simulation module is used to simulate the sound of coronae, sound of electric discharge and effects of discharge flash in high-voltage test projects, so that the process of the simulated practical training test is closer to the site scenario.

Wireless communication module: Through the wireless communication network, it realizes real-time data interaction between the test control module of arrester simulation and the teacher device.

Relevant test instruments required for finishing the arrester test are also the supporting simulation test instruments. The simulation test instruments have the identical appearance as the actual test instruments. Their interiors are the simulation systems, and they use testing wires as the simulation test wires, and only use the 12V direct current for signal transmission.

3. **Application of arrester simulation device in training**

The application of the arrester is realized through the method of "replacing high voltage with signals". First, the arrester simulation device is connected with the tester of the relevant test. After the connect signals and parameter setting signals are fed back to the teaching guidance platform and after "successful connection" and "correct parameter setting" are displayed, the teacher chooses and sends the standard or multi-type failure data to the tester. If the teacher does not operate, then a set of data stored based on on-site experience are randomly fed back to the test instrument. The test result is displayed on the tester panel, and trainees analyze the result.

Such procedures as pre-shift meeting, formality for work permit, and readout of work order must gone through before the test begins to ensure standardization of the test process, which may avoid habitual violations and correct the unsafe acts of testers on the site in a timely manner.
The pre-shift meeting mainly covers the inspection over the operating crew's dressing, physical and psychologic status, explanations about the tasks, dangerous points and safety measures, study of the operation instructions, and inspection over the safety tools and instruments. Going through the formality for work permit is a supplementary measure for the inspection over site safety measures and for the dangerous points and safety measures. The explanations about the work order mainly cover the roll call, readout of work order, and question asking. The inspection over safety tools and instruments and test instruments mainly covers the certificate of inspection, period of validity, applicable voltage grade, appearance, initial state of simulation test instruments and tested devices etc.

Electricity testing and electric discharge must be conducted for the devices before the field operation begins. The electricity testing rod used in electricity testing is equipped with the light-emitting and sounding devices. If the tested device is live, the electricity testing rod, with the help of the acousto-optic simulation module in the simulation device, will sound an alarm and flash, and transmit the signal back to the teaching guidance platform via the wireless transmission system. The discharging rod used in the discharge process is also equipped with the sound-light alarming device to simulate the flash and sound at the time of electric discharge. The sound-light alarming device and the module help trainees stay close to the actual operations, and enhance their understanding and mastery of the test.

Before the test begins, the working power must be switched on, and the leakage protection device must be checked for normal use.

Now we will give a detailed introduction to the applications in four training scenarios for the arrester simulation device, namely the insulation measurement, counter test, leakage current test under DC 1mA voltage and 0.75U1mA, and leakage current test under the working voltage.

3.1 Insulation measurement

The arrester has a very high insulation value when it is properly sealed, and will significantly decrease after being affected with damp. Therefore, the measurement of the insulation resistance of the zinc oxide arrester can effectively check the defects caused by any damaged seal, such as being affected with damp or crack of porcelain housing. The panel of the insulation resistance tester used in the test is as shown in Figure 2.

![Figure 2. Panel of Insulation Resistance Tester](image)

The surface of the porcelain housing of the tested device should be cleaned before the test so as to ensure the accurate measurement result. Before the test, the insulation resistance simulated tester must be checked for open circuit and short circuit. The insulation resistance is infinite in case of open circuit, and is 0 Ω in case of short circuit, which indicate that the insulation resistance testert passes the inspection and may be used.

Wiring is conducted first during the test. The arrester is firmly connected with the calibrating terminal of the tester with the special testing wire, and the ground lead is connected. The wiring is as shown in Figure 3, including two kinds of wiring for insulation measurement, namely insulator body insulation and base insulation.
After wiring is finished, the test parameters are set, and the arrester simulation device is used to feed the signals "correctly wired" and "parameters correctly set" back to the teaching guidance platform. Figure 4 is the result displayed on the panel in case of wiring errors.

Then the insulation resistance tester is used to apply voltage. After virtual voltage applying is finished, the teacher sets or the system randomly produces a set of insulation resistance data based on the field practice, transmits and displays them on the tester panel. In particular, the tested device must be fully discharged with the discharging rod after each insulation resistance test.

After the test is over, the test instrument will display the absorption ratio and insulation resistance, and trainees keep records of and analyze the measurement data. Through the normal or multi-type failure data set by teachers or the system, the arrester state and possible failure positions and causes are analyzed, which effectively avoids the disadvantage that trainees' ability of troubleshooting can not be built up and improved from the single test result of the field test.

3.2 Counter test
The discharge counter is used to determine whether the arrester acts in the operation, and keep records of the number of actions, so as to accumulate data and help analyze field accidents[4]. Moisture may enter the discharge counter during the operation due to poor sealing, which rusts the inner components, and causes the counter to act incorrectly. Therefore, periodic tests must be conducted to determine whether the counter is in good conditions and acts normally.
For discharge counting, the special tester for the arrester discharge counter that can produce the simulated standard lightning voltage and current is mostly used at present. Start the device after wiring is correct. Press the Action button on the device, make the impact current act on the discharge counter, and keep records of the actions. Normally conduct testing for 3-5 times.

3.3 Leakage current test under DC 1mA voltage and 0.75U1mA

The U1mA of the zinc oxide arrester is measured, mainly to check whether the valve plate is affected with damp or aged, and to determine whether its action performance meets the requirements. The permissible working current is directly related to the service life of the zinc oxide arrester. The leakage current under 0.75 U1mA is the test index for its service life, because the direct voltage under 0.75 U1mA is normally higher than the highest working phase voltage. Therefore, the long-term permissible working current should be checked for compliance with requirements under such voltage.

This test may be conducted only when the insulation resistance test is normal. In the test, mainly the simulated DC high-voltage generator is used, whose appearance is the same as that of the actually used instrument on the site, as shown in Figure 5.

![Figure 5. DC High-Voltage Generator](image)

Conduct wiring first. After making sure that the voltage output is at the zero position, turn on the power, start the simulated DC high-voltage generator, adjust the parameters, and then conduct tests.

Directly increase the voltage first. Slowly increase the voltage to the specified value after the current reaches 200μA. Read the voltage value when the current reaches 1mA. Decrease the voltage to 0.75 U1mA, read and keep records of the leakage current value. Finally, decrease the voltage to zero. Trainees keep records of the test results and analyze the cause.

3.4 Leakage current test under working voltage

The measurement of the AC leakage current under the working voltage may reflect the operation status of the arrester to some extent. Normally, the current that flows through the arrester is mainly the capacitative current, and the resistive current only accounts for a very small part. When the valve plate ages, the arrester is affected with damp, and the internal insulated parts are damaged and the surface is seriously contaminated, the capacitative current does not change much, but the resistive current greatly increases. Therefore, the measurement of the AC leakage current of the arrester under the working voltage is the main method to monitor the operation status of the arrester on the site, and the resistive current, in particular, is of great importance in detecting the damp-affected zinc oxide arrester.

The leakage current test under the working voltage is mainly composed of the live test and power outage test.

3.4.1 Live test

Conduct wiring according to Figure 6.
Check the secondary terminal number of the voltage transformer first while choosing the voltage signal. The signal can be led only from the measurement terminal instead of the protection terminal, so as to avoid misoperations. After the parameters are got, the terminal at the mutual inductor side should be removed first for the voltage lead, then the terminal on the panel should be removed, otherwise short circuit may be easily caused.

3.4.2 Power outage test
Conduct wiring according to Figure 7.

Increase the voltage to the continuous running voltage and system running voltage. Keep records of the peak value and effective value of the total leakage current, and the peak value and active loss of the resistive current respectively, and decrease the voltage to zero.

4. Feature of application of arrester simulation device
Through the detailed description of the application of the arrester simulation device in training, we may find that the arrester simulation device is similar to the real arrester and test instrument, but the former uses signals to replace the high voltage, which may give consideration to both safety and authenticity. Meanwhile, this simulation device may also meet such training requirements as real-time monitoring, failure presetting, and control of test results. Its advantages are mainly reflected in the following six aspects:

4.1 Authenticity
The arrester simulation device is the same as the real device in terms of appearance. The instruments, wire and safety tools used in the test are the same as those on the operation site, which vividly reproduces the field test process of the arrester.

4.2 Standardization
On the training site, the arrester, test instruments and safety tools are subject to the standard Fixed Location Management to ensure standardization of devices, tools and instruments. During training, the standard workflow is strictly implemented to ensure process standardization. The standardized test
training concept helps correct those habitual violations of operational regulations and avoid unsafe acts.

4.3 Safety
In the arrester test training, the chances of damage to test instruments and tested devices or personal electric shock resulting from low skill levels, insufficient on-site experience and improper operations of trainees will greatly increase. Therefore, it is particularly necessary to take the measure of "replacing actual high voltage with signals" in the test training.

This paper describes the use of the wireless communication system to realize information transfer between the arrester simulation device and teacher guidance platform, and the use of the 12V DC insulated conductor to realize the electrical connection between the test instrument and simulation device for the arrester-related tests. This avoids potential safety hazards and safeguards personal and device safety from the source in the current circumstance where the vast majority of skill training on arrester tests still relies on field practice.

4.4 Real-time monitoring
The supporting simulation control system helps meet the teaching requirement for real-time monitoring over trainee's state, including wiring self-inspection and parameter test. While trainees conduct wiring, the display interface of the guidance platform displays the wiring state and parameter setting of the current simulation instrument and tested device in a real-time manner, so that teachers can monitor trainees' wiring and completion in a real-time manner, and make corrections and give guidance in a timely manner.

Meanwhile, the 360° high-definition camera is mounted on the testing site to monitor trainees' behavior in a real-time manner.

4.5 Analysis of multi-type failure data
A number of sets of normal data and typical failure data are prestored in the test database. Teachers or the system may randomly send a set of data to trainees. In this way, the same arrester may be defined as different states (normal or failure state. Meanwhile, data of different failure types may be defined). Trainees may analyze the test results and determine the arrester state, so as to deepen their understanding and mastery of the test, which avoids the disadvantage of failure to make the multi-type fault analysis of the device in the past training due to the single test results. Meanwhile, teachers may increase the user-defined test result data, and define and save the data change in the test process based on needs.

4.6 Acousto-optic simulation
The acousto-optic simulation device is fully utilized to simulate the flash and sound at the time of discharge, so that the simulated training site more closely resembles the actual atmosphere of the site, and trainees' understanding of the test can be enhanced.

5. Conclusion
Targeting the key testing points and teaching difficulties of the arrester, as well as the applications of the arrester simulation device in four training scenarios, namely insulation measurement, counter test, leakage current test under the DC 1mA voltage and 0.75U1mA, and leakage current test under the working voltage, and by comparing with the existing similar training, this paper summarizes the device's prominent advantages in real-time monitoring, analysis of multi-type failure data, and acousto-optic simulation, which effectively solves the contradictions between authenticity and safety of the existing test training, provides a reference for further training concerned, and has a certain promotion value.
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