Development of Partial Discharging Simulation Test Equipment

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Abstract: In the case of partial discharge training for recruits who lack of on-site work experience, the risk of physical shock and damage of the test equipment may be due to the limited skill level and improper operation by new recruits. Partial discharge simulation tester is the use of simulation technology to achieve partial discharge test process simulation, relatively true reproduction of the local discharge process and results, so that the operator in the classroom will be able to get familiar with and understand the use of the test process and equipment.The teacher sets up the instrument to display different partial discharge waveforms so that the trainees can analyze the test results of different partial discharge types.

1. Introduction

Partial discharge is an important cause that results in insulation aging of electrical appliances. Therefore, partial discharge of electrical appliances must be measured in order to understand the material status of the inner insulation of electrical appliances and thus avoid insulation faults [1,2]. State Grid Corporation of China organizes professional technical skill training concerning electrical tests for its new employees every year so as to increase their work efficiency and professional competence. As a basic skill, the measurement of partial discharge must be learned. For the measurement of the testing voltage of partial discharge, high voltage must be applied. During the test, improper operations may cause damage to the test instruments or tested devices, and the risk of electric shock exists. New employees, in particular, have no field work experience, and the potential safety hazards definitely greatly increase for them if they directly use real devices for training right from the start. In addition, if a real device is used for the partial discharge test, the test result displays the waveform of partial discharge of a defect only if such defect exists in the tested device. As a result, all the measurement results of trainees are the same, which does not help trainees in their study.

In the practical training on partial discharge test skills carried out in China at present, real devices are used for hot-line work in most cases, which has limitations. Comparatively, the development and use of simulation devices for partial discharge tests lag further behind. Therefore, the teachers of Substation Maintenance Training Room of Technical Skill Training Department of Jilin Power Co., Ltd Training Center of State Grid have developed a simulation system for partial discharge tests in order to increase the teaching quality and safety of training. The system can enable the instrument display different waveforms of partial discharge, help trainees analyze the test results of different types of partial discharge, enable trainees to master more partial discharge waveforms related to defects and to simulate the process of partial discharge tests using the simulation technology. It reproduces the process and result of partial discharge relatively true, and thus enables operators to get familiar with and understand the test process and instrumental use just in the classroom. Through setting, teachers make the instrument display different waveforms of partial discharge, which helps trainees analyze the test results of different types of partial discharge.

2. Simulated training aids for partial discharge tests

2.1 Definition and cause of partial discharge

In the insulation system for electrical appliances, the electric field intensity often varies with position. When the electric field intensity in a local area reaches the breakdown field strength of such area, electric discharge will occur in the area, but such discharge does not run through the two conductors that apply voltage, that is the entire insulation system does not break down and still keeps the insulating property. Such phenomenon is called partial discharge. Such discharge is called "internal partial discharge" if it occurs in the insulator, "surface partial discharge" if it occurs on the insulator surface, and "corona" if it occurs at the edge of the conductor surrounded by gas.

Many factors cause electric field nonuniformity. (1) The electrode systems of electrical appliances are asymmetric, such as needle to plate, and cylinders. At the positions where the motor winding bar deviates from the iron core and at the high voltage leading-out terminal of the voltage transformer, electric fields are relatively concentrated at such positions as the cable terminals. Electric discharge may easily occur at these positions first if no special measures are taken. (2) Media nonuniformity, such as various composite media; gas and solid combination, different combinations of solid. In the alternating electric field, the electric field intensity in the media is inversely proportional to the dielectric constant. Therefore, the electric field intensity in a medium whose dielectric constant is small is higher than that in a medium whose dielectric constant is big. (3) The insulator contains bubbles or other impurities. The relative dielectric constant of gas is close to 1. The relative dielectric constants of various kinds of solid and liquid media at least double it, and the breakdown field strength of solid and liquid media are normally bigger than that of gas media by several times to several tens of times. Therefore, the existence of bubbles in the insulator is the most common cause of partial discharge. The bubbles in the insulator are probably left over during manufacturing, or are the cracks that emerge on the interfaces of different materials due to expansion caused by heat and contraction caused by cold during the product operation, or are the gas decomposed from aging of insulation materials. In addition, if there are stress-suspended metals in the high field intensity, high field density will also be induced at their edges. If there is bad contact at the joints of electrical appliances, the high field intensity will be produced between two connection points whose distance is tiny. All these may partial discharge.

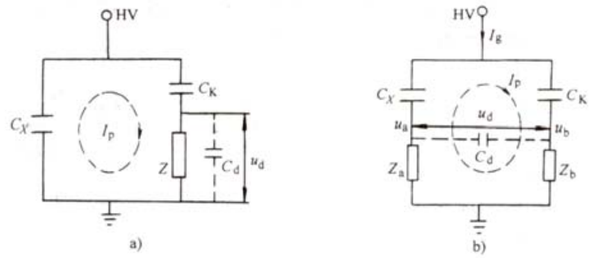
Partial discharge will gradually erode and damage insulation materials, expand the discharge area, and eventually result in breakdown of the entire insulator. Therefore, partial discharge must be restricted to be below a certain level. For high-voltage electrical equipment, the measurement of partial discharge is regarded as an important index for product quality checking. For products, not only partial discharge test should be conducted at the time of delivery from factory, but also frequent measurement is required after they are put into operation.

2.2 Detection method for partial discharge

The impulse current method may calibrate the apparent electric discharge based on the equivalent circuit of partial discharge, with a high sensitivity of measurement. It is the most widely used method, as well as the method recommended by IEC and relevant Chinese standards. This simulated training aid employs the impulse current method to measure partial discharge [3,4].

When partial discharge occurs in a certain area of the insulator, the two ends of the insulator (namely two ends of the test object to which voltage is applied) will have transient (pulse) electric charge q (apparent electric discharge). One coupling condenser CK and detection impedance Z are connected with the test object to form a circuit, as shown in Figure 1 [5,6]. There are two ways of circuit connection: one is the direct measurement method, as shown in Figure 1-a, the other is the balanced method (bridge type), as shown in Figure 1-b. The latter divides the detection impedance into Za and

Zb, and conducts neutral earthing in it. Whichever method is used, ud collected at the two ends of detection impedance is always associated with the apparent electric discharge q of the test object [7,8].



1-a Direct measurement method 1-b Balanced method

Figure 1. Schematic Diagram for Measurement Using Impulse Current Method

2.3 Simulated training aids

2.3.1 Control box and software
The front panel of the control box includes the channel port, earthing, power switch, and display panel. At the time of measurement, the coaxial cable is used to connect the ports to the junction box, and the two ends of the junction box are connected to the measurement point. When connection is normal, turn on the power, start software, and view the waveforms of partial discharge. The software interface and function are as follows:

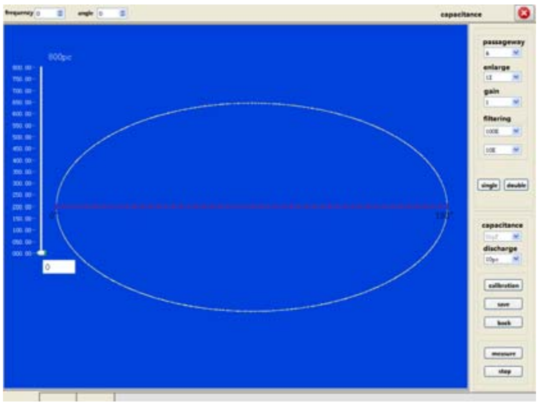


Figure 2. Front Panel of Control Box

The display interface includes the title bar, waveform display area, display selection area, channel selection, function selection, calibration function and measure/stop module of the real partial discharge tester.

At the time of measurement, connect the wire, switch the interface to the ellipse or sinogram, select corresponding channels, and click Measure to start measurement if the tester stops. Carry out such operations as blanking, windowing, and zoom in according to corresponding needs. In blanking, right click to select blanking, and left click to select the blanking area. In windowing, open single windows or double windows based on needs. Click the single window or double window button to switch to the corresponding functions, and select corresponding areas in the graphics area. In case of zoom in, select corresponding magnification times in the pull-down menu. In calibration, switch software to the calibration interface. Connect the standard pulse generator to the two ends of the capacitor. Start the calibrator, and select corresponding calibration sizes. Select corresponding electric discharge magnitudes at the software end. Click Calibrate and save setting, then click to return to the main interface.

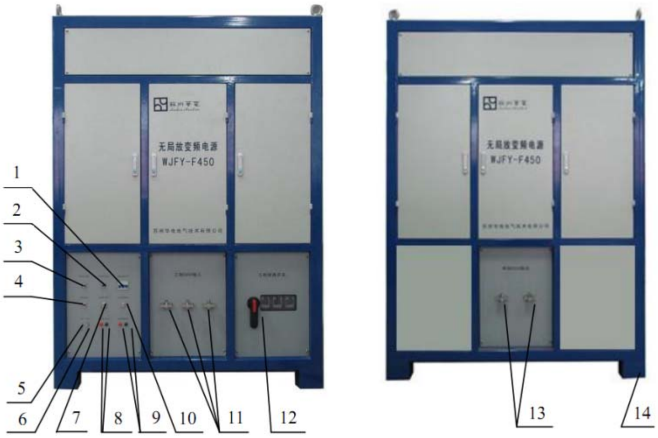
2.3.2 Standard pulse generator (simulated)

The simulated standard pulse generator is as shown in Figure 3.

Figure 3. Simulated Standard Pulse Generator

The hole above the simulator is the charger interface. Please recharge it when the battery is low. Click Power to start the impulse generator. Turn on the power. Click Calibrate to enter the calibration interface. Short press Calibrate to switch corresponding calibration quantity in sequence.0 Long press the backlight of the On/Off screen, and finish calibration with the help of the control box software.

2.3.3 Variable-frequency power cabinet without partial discharge



a) Front of variable-frequency power cabinet b) Back of variable-frequency power cabinet

Figure 4. Outside View of Variable-Frequency Power Cabinet

Note: 1. Control power switch; 2. Fibre-optic communication interface; 3. Control line interface; 4. Parallel operation signal interface; 5. Earthing of casing; 6. Output neutral earthing; 7. 7.RS232/485 communication interface; 8. Synchronizing signal interface; 9. Output interface of 220V isolated power; 10 High-voltage measurement interface; 11. Three-phase 380V AC input; 12. Three-phase isolating switch 13. Single-phase 350V AC output; 14. Supporting foot of elastic damping

The control power switch controls the electric control part and the blower fan power switch in the power cabinet. The fibre-optic communication port is the fibre-optic communication interface connected with the intelligent control cabinet. The control line interface connects with the analog control cabinet via the multicore cable. Pthe parallel operation signal interface means that when two frequency conversion cabinets are in parallel operation, they are connected with special cables, with the host connected to [Output], and the slave to [Input]. Earthing of casing refers to the safe grounding of the casing of the frequency conversion cabinet. The output neutral earthing is the filter neutral earthing of the output port of the frequency conversion cabinet. The RS232/485 communication interface is the communication interface connected with the control box. The synchronous signal interface is the isolated output of the synchronous frequency signals of the frequency conversion cabinet, with the voltage being 12V～ and the output current ＜2A (Warning: Short circuit is strictly prohibited!) The 220V power is the isolated power output by the frequency conversion cabinet, with its voltage being 220V～ and its output power smaller than 200VA. The high-voltage measurement interface is the access port of the high-voltage bleeder signal, with the maximum input voltage of not more than 20V. The input end of the variable frequency power supply is the three-phase 380V AC input. The three-phase isolating switch is the apparent cut-off point of the input power of the frequency conversion cabinet -- the isolating switch. The output port of the variable frequency power supply is the 350V output of the monophasic sine wave.

2.3.4Testing voltage

GB 1094.3-2003 prescribes the voltage applying time and steps for the partial discharge test of the voltage transformer. For voltage transformers of 110kv and above, first increase the testing voltage to 1.5Um/$\sqrt{3}$ for measurement, and keep it for 5min. Then increase the testing voltage to Um, and keep it for 5s. Decrease to less than 1.5um/$\sqrt{3}$ for measurement, and keep it for 30min/60min. We take the measure of automatic voltage boosting for measurement. Users may choose measurement bleeders of different specifications based on configuration and specific test conditions.

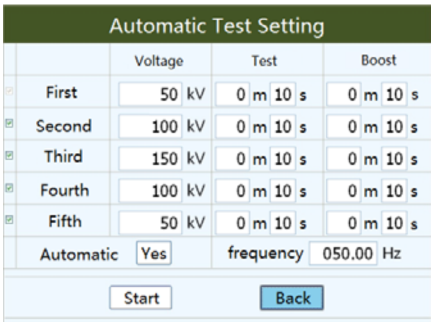


Figure 5. Setting of automatic test

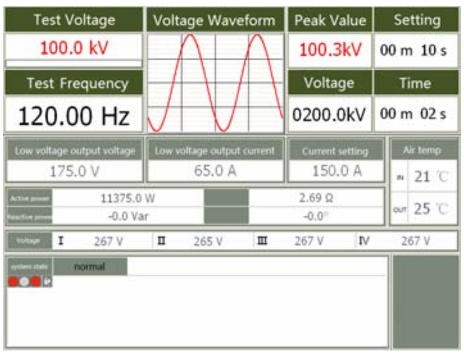


Figure 6. Interface of Automatic Test

3. Wiring detection and realization process

The simulated training aids for partial discharge tests simulate the process of electrical tests using the simulation technology. The simulated tested device and simulation instrument have the same appearance design as the real transformers, and their terminals and identifications are basically the same as those of real power grid devices. It reproduces the process and result of partial discharge tests relatively truly, and thus enables operators to get familiar with and understand the test process and instrumental use just in the classroom. The test wiring and real wiring are the same, and the teaching aids can also measure whether wiring is correct [9].

According to the requirements of the test concerned, first conduct wiring according to the order of wiring in the wiring diagram. Connect the simulation instrument with the simulated tested device with the simulation test wire. The simulation instrument outputs signals to the simulated tested device via the simulation test wire. The signals are transmitted to the simulation module in the simulated tested device via the simulation test wire. The simulation module feeds the signals back to the simulation instrument via the simulation test wire. The simulation device receives the signals fed back by the tested device, and checkes whether wiring is correct. After detecting any wiring errors, the simulation instrument is always in the standby mode, and can not test the tested device until wiring is correct. Teachers may set the measurement results. The data of collected by the database come from the actual test results and the empirical data from a number of measurements. That is, they contain the test data of the tested devices in normal states, as well as the test data of the tested devices in failure states, so that the content displayed by the simulation instrument has more authority and guiding significance.

Several common waveforms of partial discharge are given here.

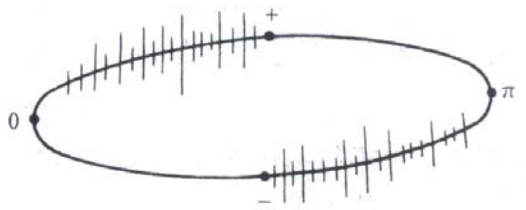
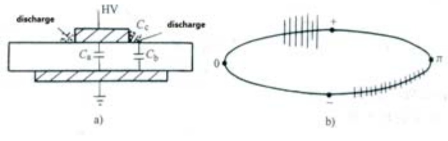


Figure 7. Electric Discharge of Internal Bubbles of Media

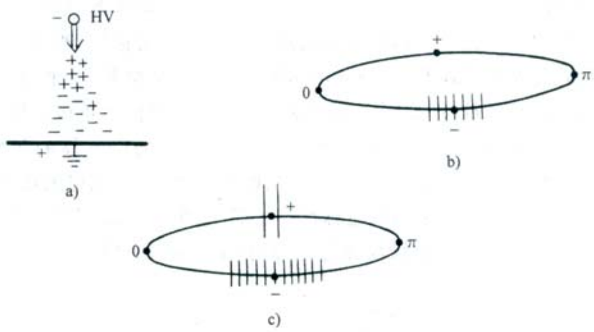
Figure 7 shows that electric discharge does not emerge in a phase of the overpeaked value of the testing voltage, which is in line with the above explanation about the discharge process. However, the magnitude of each electric discharge, namely the pulse height, varies. In addition, electric discharge mostly occurs in the phase of the ascending portion of the absolute value of the testing voltage amplitude. It will expand to the phase of the descending portion of the absolute value of voltage only when electric discharge is intense. This is probably because it is often the case that a number of bubbles discharge electricity at the same time in real test objects, or there is only one big bubble. However, each electric discharge occurs not on the entire bubble surface, but on a part of the surface. Apparently, the electric charge of each discharge is not necessarily the same. Besides, the original electric charge accumulated will not necessarily be neutralized in the back discharge. Instead, both the positive and negative charge accumulate near the bubble wall, and thus produce surface discharge along the bubble wall.



a)Discharge model b)Discharge pattern

Figure 8. Diagram of Surface Partial Discharge

The electric charge produced in the discharge can only accumulate on one side of the medium. Therefore, with less electric charge accumulated, discharge does not easily occur in the descending phase of the absolute value of the applied voltage.



A) Discharge model b) in case of initial discharge c) in case of very high voltage

Figure 9. Diagram of Corona Discharge

Electric discharge occurs right near the pinpoint. As electron emission easily occurs in case of the negative polarity and meanwhile positive ions hit the negative pole to incur secondary electron emission, electric discharge always occurs first when the pinpoint has the negative polarity. At this point, positive ions quickly move to the pinpoint electrode for recombination. While electrons move to the plate electrode, they are attached to neutral molecules and become negative ions. Negative ions migrate slowly. Many negative ions move to the plate electrode or the applied voltage increases, the electric field near the pinpoint again rises to the breakdown field strength of gas, and therefore the second electric discharge occurs.

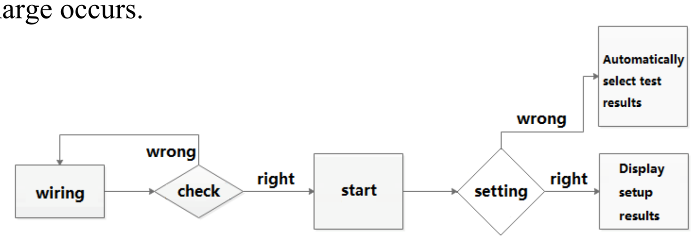


Figure 10. Test Flow Chart of Simulated Training Aids for Partial Discharge Test

4. Conclusion

This partial discharge simulation tester particularly aims at new employees who lack the experience of field work, and whose limited skill levels and improper operations etc. will definitely increase potential safety hazards greatly. Simulating the process of the partial discharge test using the simulation technology can reproduce the process and result of partial discharge tests relatively truly, and thus enable operators to get familiar with and understand the test process and instrumental use just in the classroom. Teachers may increase the user-defined test result data, and define and save the data change in the test process based on needs. The entire system is highly safe, with no potential safety hazards such as high voltage or induced electricity or residual charge which may hurt people, and will not result in personal injury or equipment damage even in case of wrong wiring.

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