Discussion on Application of Parallel Compensation Resonance Technology in AC Withstand Voltage

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Abstract. Preliminary exploration of the application of parallel compensation resonance technology in AC withstand voltage. Using the most commonly used power frequency AC withstand voltage method in daily electrical tests, a compensation capacitor and a compensation reactor are connected in parallel on a large capacitance sample, and the capacitance value in the circuit is adjusted by adjusting the value of the compensation capacitor and the compensation reactor. When the inductance value is equal to or close to equal, the test power supply and test equipment can input a higher AC voltage under the condition of small capacity, thus completing the AC withstand voltage test of the high-voltage and large-capacity test samples.

Keywords: Large capacitance sample; Capacitive reactance; Inductive reactance; Parallel compensation; Parallel resonance.

1. Introduction

After the mid-1990s, for medium and high-voltage power cables using cross-linked polyethylene as the insulating medium, the voltage test of the main insulation required AC voltage test; since the cable is defined as a capacitive test product, the test voltage using power frequency is in principle impossible to complete the work on the job site. Therefore, the frequency conversion resonance method is used at the construction work site. [1,2] The "series frequency conversion resonance AC withstand voltage test" equipment currently used internationally is heavy, large volume; according to the capacitance of the tested product, the wiring of each part has changed, and the overall wiring is also very complicated. At the same time, in order to ensure the safety of personnel, equipment and the tested product, it is calculated and tested according to the condition of the tested product before the test. For the check calculation, a complicated use plan must be written. [3] During the test, the operation is complicated, with many variables, and the frequency is between 30 and 300 Hz, which is inconsistent with the actual operating frequency.

The "micro differential two-way compensation power frequency withstand voltage tester" we developed, the principle of the circuit is that RL is connected in series with C. When the power frequency voltage is applied to the capacitive test product-the power cable, a capacitive current will be generated, and the inductance will also be There will be an inductor current in the opposite direction of the capacitor current, and the two compensate each other. When the capacitive reactance in the circuit is approximately equal to the inductive reactance, it will enable us to complete the power frequency of the tested product under the condition that the power supply capacity is very small. [4,5] AC withstand voltage test. The characteristics of this circuit are: power frequency output, calculation, wiring and operation are simple and clear.
2. Principle

2.1. Frequency Conversion Resonance Method
The test circuit of the frequency conversion resonance method is composed of a high-voltage resonance main circuit and a frequency conversion voltage regulation circuit. Its working principle is: a fixed reactor and a test product are used to form a high-voltage resonance main circuit. First, the output frequency of the inverter is adjusted so that the main circuit reaches resonance state, and then adjust the voltage of the voltage regulator to make the tested cable reach the preset withstand voltage value. Compared with the power frequency withstand voltage test, the frequency conversion resonance method does not need to configure an adjustable reactor, and only needs to add a frequency modulation power supply device. With the development of power electronic technology and the maturity of high-power frequency conversion test equipment manufacturing technology, the frequency conversion resonance method has a specific relative advantage in equipment cost. [6] At the same time, due to the wide frequency adjustment range of the variable frequency power supply (generally up to a few hundred hertz), only a few fixed inductors with different inductance values are needed to achieve the AC withstand voltage test for cables of various lengths.

2.2. Improvement Method
Power cables are developing rapidly in China. The insulation medium of power cables is mainly cross-linked polyethylene. Due to the influence of electrical branches in the medium, in the middle and late 1990s, whether it was State Grid or Southern Power Grid, It is clear in the test regulations that the DC high voltage method cannot be applied to the XLPE insulated dielectric cable for the voltage test, and the AC voltage method must be used.

Judging from the field test situation for many years, there are many deficiencies in the series frequency conversion resonance method. In order to ensure that the input frequency is between 30 and 300 Hz, and at the same time, the input current and voltage must meet the test requirements, this requires multiple reactors For series and parallel connection, in order to output enough current and voltage, the corresponding excitation transformer has many sets of coils inside, which are also bulky and heavy; moreover, there are frequency conversion electronic circuits in the operation box of the frequency conversion power supply, transportation, maintenance and on-site adjustment are all Many uncertain factors influence the results, especially for long-distance cables or large-capacity test specimens, the configuration calculation of the test instrument is very complicated, even many professional testers cannot calculate accurately, and the frequency conversion power supply is mostly The electronic circuit is composed of a large-capacity output, and some failures often occur, which is the main reason that the field test cannot be completed 100%.

In this regard, the subject we conceived is to find a new method that can ensure that the power capacity required by the test is not greater than the power capacity of the series conversion resonance mode, and that the test is an AC withstand voltage test, and the optimal output frequency is 45 ~ 55Hz, close to power frequency; compared with series resonant AC withstand voltage equipment, the volume is smaller, the weight is lighter, the wiring operation is relatively simple, the test equipment is stable and reliable, the test method and results fully meet the requirements of the test regulations, the current plan is to use inductance In the mutual compensation method with the capacitor, this project is to increase the voltage of the tested product according to the principle of mutual compensation of the capacitor and the inductor in parallel, and it is expected to provide a new idea for the voltage test of the cable and large-capacity equipment.

3. Project Research Content

3.1. Main Technical Content

3.1.1. Theoretical study on power frequency voltage bidirectional compensation power frequency withstand voltage test. Taking the cable of our office as the application object, the length and type of each cable of our office are counted, the capacity of the cable line is estimated, and more than four
phase-shift capacitors are used in the laboratory to form an analog cable. Form a model of "difference two-way compensation power frequency withstand voltage tester" and collect parameters. On this basis, the calculation and selection of the capacity of the AC high-voltage generation part, the calculation and selection of the inductance, current, and voltage required to compensate the inductor, and the calculation and selection of the capacitance, voltage and compensation required by the compensation capacitor, are R & D lays a theoretical foundation.

3.1.2. Circuit design and structure design of the device. According to the theoretical research results, the circuit design and structure design of the device are carried out. mainly include:

(1) Compensation reactor
(2) Compensation capacitor
(3) Control part of power frequency withstand voltage device
(4) Other accessories

3.2. Main Technical Difficulties
Theoretical research on power cable voltage differential bidirectional compensation power frequency withstand voltage test, including capacity calculation and selection of AC high-voltage generation part, calculation and selection of inductance, current and voltage required for compensation inductance, and capacitance required for compensation capacitor, Voltage calculation and selection, etc. The research on the adjustment method of compensation inductance, how to develop a compensation inductance with small size, convenient on-site adjustment, and simple and practical wiring is a technical difficulty and key point of this project. The research on the adjustment method of compensation capacitor, how to develop a compensation capacitor with small size, convenient on-site adjustment and simple and practical wiring is another technical difficulty and key point of this project.

3.3. System Functional Block Diagram and System Schematic Diagram

![Figure 1. Functional block diagram of differential two-way compensation power frequency withstand voltage tester.](image-url)
3.4. Test Method and Main Equipment Composition Design

3.4.1. Implementation of system functional block diagram and schematic diagram. Taking the current 10kV cable in the operation of the power grid as the application object, estimating the capacity of the cable line, applying a 30kV capacitor in the laboratory, performing series and parallel connection to form an analog cable consistent with the operating cable parameters, and applying the commonly used power frequency AC Withstand voltage test equipment, form a "difference two-way compensation power frequency withstand voltage tester" model, and collect data. On this basis, first use special adjustable inductance and capacitance to form a two-way compensation power frequency withstand voltage test circuit, and compare with the existing "series frequency resonant AC withstand voltage test" equipment to verify the feasibility of the test. Based on the verification of a single feasibility test, the calculation and selection of the capacity of the AC high voltage generation part, the calculation and selection of the inductance, current and voltage required for the compensation inductor, and the calculation of the capacitance and voltage required for the compensation capacitor, etc. Thereby laying a theoretical foundation for the research and development of the device.

3.4.2. Realization of compensation inductance and compensation capacitance adjustment. According to the above requirements, a compensation inductance and compensation capacitor that are suitable for on-site handling and convenient on-site adjustment are specially designed. For this link, it is necessary to repeatedly practice and verify the comparison until it meets the actual requirements.

4. Implementation Plan

4.1. Subject Preparation
The tested object was a 7.2 km 10 kV cable line. The cable mid-joint accessories were newly replaced. One end of the line was connected to the GIS inside the substation through the cable GIS terminal, and the other end was connected to the transmission overhead line through the outdoor porcelain sleeve terminal. At the site, the drainage line on the overhead line side was removed, the cable terminal was suspended, and the GIS incoming air chamber was disassembled and installed with a high-pressure test sleeve. During the test, the high-voltage lead is connected to the high-voltage test sleeve to realize the voltage application to the cable under test. On the other hand, because all cable lines are arranged in the tunnel, cross interconnection systems are set every 500 meters. Before the test, the cross interconnection grounding box and the protector in the grounding box must be Short.
4.2. Design of Control Part of Power Frequency Withstand Voltage Device
Design small, light structure, including feedback direct reading voltage display and input voltage and current display, can fine-tune the input frequency, with short circuit, over current protection function.

4.3. Design and Production of Compensation Inductor
Based on the normal value of commonly used test products, for example, the most commonly used 10kV on our power grid is the YJLV22-8.7 / 15-3 × 300 cross-linked polyethylene cable, and its capacitance per kilometer is 0.37 microfarads, The corresponding compensation inductance value is 27.4H, so the parameters of each of our designed electrical inductance are: inductance value 27.4H, voltage 20kV, current 3A; weight about 35kg.

4.4. Design and Manufacture of Compensation Capacitors
Preliminary consideration is to use parallel connection for design. Six to ten dry capacitors with different capacitance values are used. The minimum value is 0.01 microfarads and the maximum value is not more than 0.37 microfarads. In this way, the total value is 0.37 microfarads through parallel adjustment the degree reaches 0.01 microfarad, so as to ensure that all lengths of cable can be tested.

4.5. Test Implementation
The voltage withstand voltage test should not be applied too quickly. After finding the resonance point, boost it. After the voltage boost reaches 75%, it can be boosted at a test voltage of 2% per second. After reaching the test target voltage, it continues for 60 minutes. Through the field test of 10kV I-circuit and II-circuit cable lines, the data results are the same as the theoretical calculations, and the validity of the theoretical calculations is verified. At the same time, it is also the first time to realize the on-site AC withstand voltage test of the long-distance large-capacity cable of the cloud network. It is of great significance to promote related experiments.

5. Summary
Through the above work, the key objectives of this project research are basically achieved:
Solve the problem that the output frequency of the existing series frequency conversion resonance AC withstand voltage test method is inconsistent with the actual operating frequency; solve the problems of complicated wiring and instability in the test process of the existing series frequency conversion resonance AC voltage test method; solve the existing series frequency conversion resonance AC The pressure test method is cumbersome to calculate and requires high level of personnel; it solves the economic problem of high cost of equipment in the existing series frequency conversion resonance AC voltage test method.

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