Causes and solutions of a group split of resistance-capacitance absorber for parallel reactor

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Abstract. The resistance-capacitance absorber is used in conjunction with the shunt reactor and is an important power grid equipment used to absorb the intercepted over-voltage generated during the switching process of the vacuum circuit breaker. However, the quality of the RC absorber itself affects the normal operation of the system to a certain extent. In this paper, group-cracking and oil-spilling fault of RC absorber in a 220kV transformer substation is on-site inspection, comparison test and disintegration. On this basis, solutions have been proposed, which have a certain significance to solve the group-cracking and oil-spilling fault of RC absorber.

1. Introduction
With the rapid development of power systems, the problems of operation and power frequency overvoltage and their protection measures are becoming more and more important. The resistance-capacitance absorber is widely used because of its ability to effectively absorb overvoltage and suppress resonance. However, the technology and quality level of RC absorbers from various manufacturers are uneven. In recent years, various failures of RC absorbers have frequently appeared. In this article, the author conducts an experimental dismantling of a 220kV RC absorber group crack fault, analyzes the cause of the group crack fault, and gives corresponding solutions and suggestions for this type of fault. [1]

2. Basic failure situation
In May 2020, a 220kV substation operator discovered during the inspection that 10 of the 18 units of the station had ceramic sleeve cracking and oil leakage in the capacitor part of the RC absorber. After the operator found the problem remove the faulty equipment in time.

The substation operates 3 sets of 220kV three-winding single-phase main transformers, each with a capacity of 150MVA. The main transformer has three voltage levels. The 220kV system adopts the 3/2 circuit breaker connection method. Each transformer has a 35kV busbar. The 35kV busbars of the three main transformers are connected to a set of dry-type iron core shunt reactors. The capacity of 35kV shunt reactor is 400kVA. The circuit breaker used in front of each parallel reactor is a vacuum circuit breaker, and a resistance-capacitance absorber is connected in parallel before each parallel reactor. [2]

3. On-site inspection
The RC absorber used in this station has a rated voltage of 35kV, a rated capacitance of 0.6µF, and a resistance value of 40Ω. The device model is LG35-0.6/40-1. The RC absorber consists of two 0.3µF
capacitors in parallel. It is connected in series with a 40Ω resistance box, which was delivered in January 2012 and put into operation in July 2012. [7]

On-site inspection found that: there are 10 RC absorber capacitors in this station that have ceramic sleeve cracking and oil leakage to varying degrees. The 1# capacitor has the most serious cracking, as shown in Figure 1, from the top of the ceramic sleeve to the bottom of the ceramic sleeve. Cracks, there are small cracks at the bottom of the porcelain sleeve, and there are a lot of oil stains around the cracks. No malfunctions were found in the resistance box of the RC absorber.

4. Diagnosis test and disintegration

In order to analyze in detail the cause of the partial cracking of the capacitor in the RC absorber, a number of tests were carried out on a cracked capacitor and an uncracked capacitor. The partial discharge, capacitance, and dielectric loss measurements of the two devices did not find obvious abnormal. [4]

4.1 Test analysis

4.1.1. Color penetration testing

In order to analyze in detail the cause of the partial cracking of the capacitor in the RC absorber, a number of tests were carried out on a cracked capacitor and an uncracked capacitor. The partial discharge, capacitance, and dielectric loss measurements of the two devices did not find obvious abnormal. [5]

After cleaning the dirt on the surface of the two equipments, first use color penetrating flaw detection technology to color and spray the surface of the two equipments respectively, in order to observe the small cracks hidden on the surface of the equipment. The test shows that the original cracked equipment has an obvious irregular crack from three-quarters to the bottom of the equipment, with a few pores on the surface, as shown in Figure 2. The original uncracked equipment has no cracks found except for a few pores on the surface, as shown in the figure. 3.

Figure 1 1# fault capacitor
4.1.2. Partial discharge measurement and UV instrument observation

In May 2020, a 220kV substation operator discovered during the inspection that 10 of the 18 units of the station had ceramic sleeve cracking and oil leakage in the capacitor part of the RC absorber. After the operator found the problem, the faulty equipment was removed in time. [6]

Special partial discharge test equipment is used to measure partial discharge of two capacitors with cracks and without cracks to check the insulation performance of the equipment. After pressurizing to 20kV, record the test data. According to the order technical agreement, the partial discharge of the RC absorber capacitor is not more than 50pC, the test data is shown in Table 1, and the test result is qualified. In addition, after pressurizing to 25kV, the surface of the equipment was observed with an ultraviolet instrument, and no discharge was found.
Table 1 Partial discharge test data and UV instrument observation results

| Pilot projects | Partial discharge measurement (pC) | UV instrument observation results |
|----------------|-----------------------------------|----------------------------------|
| Cracked capacitor | 32.9 | No discharge is found |
| Uncracked capacitor | 43.2 | No discharge is found |

4.1.3. Dielectric loss tangent value tanδ measurement, capacitance value measurement
Dielectric loss tangent value tanδ measurement and capacitance value measurement were carried out on two capacitors with cracks and without cracks. The measurement results are shown in Table 2. The dielectric loss tangent value has no obvious change compared with the factory value. The test capacitance value meets the requirement that the standard deviation between the capacitance of a single capacitor and the rated value in the state maintenance test procedure should be between -5% and 10%, and the initial value difference is less than ±5%.[7]

Table 2  Dielectric loss tangent value tanδ, capacitance value

| Pilot projects | Voltage value (V) | Current value (mA) | Dielectric loss tangent tanδ (%) | Capacitance (µF) | Capacitance deviation |
|----------------|-------------------|-------------------|---------------------------------|-----------------|-----------------------|
| Cracked capacitor | 499.9 | 47.54 | 0.040 | 0.303 | 0.10% |
| Uncracked capacitor | 500.3 | 47.81 | 0.034 | 0.304 | 0.13% |

4.2 Anatomical analysis of faulty capacitors
In order to further confirm the cause of the capacitor group cracking and oil leakage in the station, one of the cracked capacitors was dissected and analyzed. The following problems were discovered during the anatomy and analysis of the cracked capacitor: After breaking the outer ceramic sleeve, it was found that two large pores, a few small pores and part of the epoxy resin fell off on the second-layer casting surface of the capacitor. The thickness of the second layer of epoxy resin casting is uneven, the weak layer is about 0.1cm, and the thicker layer is about 0.5cm-0.6cm. The connecting wires of the 6 capacitor bank layers inside the device are not completely sealed in epoxy resin after being sealed with insulating tape. The black insulating tape of the connecting wires can be clearly seen on the casting surface of the second layer, because the connecting wires are sealed on the casting surface. The reason is that there are large pores near the connecting line of the second layer casting surface. There is oil leakage in cracks on the surface of the porcelain sleeve. When the porcelain sleeve and the second layer casting surface are broken, oil stains are obvious between the capacitor bank layers and the inside of the second layer casting surface. [8]

5. Cause analysis
According to the basic conditions of the substation, on-site inspections, various diagnostic tests, anatomical conditions, etc., an in-depth analysis of the cause of the group split failure of the capacitors in the RC absorber of the station is conducted. [9]

5.1 Process aspect
The product manufacturing process has defects, and there are a lot of pores on the surface and inside of the cast epoxy resin. When a layer of epoxy resin is cast and placed in a porcelain sleeve for secondary casting, the position of the first layer of casting is skewed and not in the middle of the porcelain sleeve, resulting in uneven thickness of the second layer of epoxy resin; connection of capacitor bank layers The wires are not completely cast in the epoxy resin, and most of them are
exposed on the second-layer casting surface. There are large pores around the bare wires, which causes the insulation strength of the capacitor to decrease; due to the defects of the casting process, there are a lot of voids inside and on the surface of the epoxy resin. After the sleeve is cracked due to some reasons, oil stains on the surface of a layer of cast internal capacitor will leached out the porcelain sleeve.

Although the test results of partial discharge, ultraviolet, dielectric loss, and capacitance measurement are qualified, the process defects of these RC absorbers cannot be ignored. When the equipment is running for a long time to generate heat, the outer porcelain sleeve is cracked, or the power grid has large fluctuations, these hidden defects are likely to cause major equipment failures and endanger the power grid and personal safety.

5.2 Material aspect

Through anatomy, it was found that, except for the obvious cracks on the surface of the porcelain sleeve, no cracking was found in the internal epoxy resin casting body, indicating that the epoxy resin casting body was more effective than the epoxy resin casting body under the same operating conditions such as temperature, humidity, voltage, current, and frequency. Porcelain sleeve has stronger toughness. A layer of casting body is put into a porcelain sleeve and injected with epoxy resin, and then heated to cure the gel for secondary casting. Since epoxy resin and porcelain sleeve are two different materials, the thermal expansion coefficients of the two are different. When the product is put into and out of operation, stress or internal stress will be generated due to temperature changes. The internal stress can be calculated and analyzed according to the basic formula of material mechanics (stress=deformation×modulus):

\[ \delta \approx (\Delta L_s + \Delta L_a) \times E_r = [\Delta L_s + (a_r - a_w) \times \Delta t] \times E_r \]  

(1)

\( \delta \) is the internal stress, \( \Delta L_s \) is the amount of deformation when the resin shrinks and expands, \( \Delta L_a \) is the amount of deformation caused by the difference between the expansion coefficient of the resin and the porcelain sleeve, \( a_r \) is the thermal expansion coefficient of cured resin, \( a_w \) is the thermal expansion coefficient of porcelain sleeve, \( \Delta t \) is the temperature difference, \( E_r \) is the resin elastic modulus.

The average thermal expansion coefficient of epoxy resin is 65×10⁻⁶m/°C, the average thermal expansion coefficient of porcelain material is 3×10⁻⁶m/°C. The difference between the two is an order of magnitude, and there is a large internal stress between the two. When the RC absorber encounters a drastic change in cold and heat, a strong current impact, or an external force, the porcelain sleeve is easily cracked. Therefore, the internal stress caused by the large difference in expansion coefficient between the epoxy resin and the porcelain sleeve is also the main reason for the cracking of the porcelain sleeve of the RC absorber.

6. Measures and recommendations

In view of the group cracking and oil leakage of the RC absorber, the following measures are recommended to discover the problem in time to avoid similar failures from happening again. The internal stress caused by the large difference in expansion coefficient between the epoxy resin and the porcelain sleeve is the main reason for the cracking of the RC absorber. It is recommended that the manufacturer improve the material of the outer porcelain sleeve while improving the casting process and the vacuum process, such as Do not use the second casting of the outer ceramic sleeve, but adopt the full epoxy resin casting technology, or use the metal shell oil-immersed capacitor to replace the outer ceramic sleeve capacitor, so that there is no stress problem between the epoxy resin and the outer ceramic sleeve and prevent The RC absorber is cracked. [10]

Process defects such as the capacitor casting process and vacuuming process in the RC absorber are important reasons for the leakage of oil from the surface of the equipment, and the hidden dangers of insulation caused by these process defects cannot be ignored, so the improvement of the
manufacturing process of the RC absorber. It is also an inevitable way to improve product quality and reduce operating failures.

If the above-mentioned faults of the RC absorber are found, the infrastructure in the station can be analyzed, and the equipment can be modified if conditions permit. For example, the vacuum switch in front of the shunt reactor is transformed into a sulfur hexafluoride switch, and the resistance-capacitance absorber is completely separated from the power system, which fundamentally reduces the equipment failure rate and improves the stability and safety of the grid operation.

At present, it is necessary to strengthen the daily inspection and monitoring of the same process products, and focus on checking whether there are cracks and oil leakage in the outer porcelain sleeve of the RC absorber. Similar problems are found and solved in time. There is no effective means to monitor the operation of the resistance-capacitance absorber at the scene, and it can only rely on the operators to find problems in daily inspections and monitoring. Conventional monitoring such as infrared thermal imaging and ultraviolet discharge online testing and diagnosis are difficult to find the fault of the RC absorber in the first time. Therefore, other monitoring methods should be explored to effectively monitor the state of the RC absorber, and to find faults such as cracks and oil leakage in time. In order to avoid its failure to cause greater harm to the power grid and personnel.

7. Conclusion
The resistance-capacitance absorber is a kind of power equipment used in conjunction with shunt reactors, which can effectively limit the amplitude and frequency of overvoltage, and to a large extent reduce the damage of overvoltage to the insulation of the equipment, but the quality problems of the resistance-capacitance absorbers caused by defects in design, material, etc. are extremely prone to various failures after being put into operation, which pose a certain threat to the safe and stable operation of the power grid. Therefore, it is urgent for manufacturers to improve technology and improve design. If conditions permit, equipment transformation can also be carried out, such as the transformation of the capacitor part of the RC absorber and the transformation of the vacuum circuit breaker, which can also effectively reduce the failure rate of the RC absorber and improve the safety and stability of power grid operation.

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