Cause analysis and improvement of 500 kV capacitive bushing end shield fault

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Abstract: Aimed at solving the problem of the end shield fault of 500 kV capacitive bushing which happened frequently in the main power grid in recent time, two faults are taken as examples to analyze the fault characteristics and reasons of the spring cap type end shield devices. On that basis, effective revention measures and modification schemes for the spring cap type end shield devices of 500 kV capacitive bushing are proposed from perspectives of the equipment security operation and maintenance, and personal safety.

1. Introduction

The high-voltage bushing is an important part of the main equipment such as transformers and shunt reactors. It draws the high-voltage leads from the cabinet of the equipment and plays a role in insulating the shell of the high-voltage leads [1]. At present, transformer bushings with voltage levels of 110 kV and above generally use oil-paper capacitive structures. The oil-paper capacitive bushings are rolled by the principle of capacitor voltage divider. The capacitor core composed of insulating paper and conductive aluminum foil is used as the internal insulation structure. The jacket is used as external insulation, and qualified transformer oil or SF6 is injected in the middle to play the role of insulation and heat dissipation [2-3]. Recently, there have been many 500 kV capacitive bushing end shield failures in the power grid. This article takes two of these failures as examples to analyze the causes of the failure of the end shield and propose effective improvement measures.

2. Analysis of the structure and failure mechanism of the end shield the last

2.1 Introduction to the end shield structure

In order to ensure that the end shield is kept at ground potential during the normal operation of the capacitive bushing, and the end shield is kept insulated from the ground during the power failure maintenance test, the end shield device is designed in the project. Among them, the spring cap type end shield is a relatively widely-operated structure, and its structure diagram and physical diagram are shown in Figure 2.
The end shield of the casing is finally grounded through the spring, the lead post, the grounding sleeve, and the grounding cover. The grounding path of the end shield during normal operation is shown in Figure 3.

2.2 Failure mechanism analysis
The possible reasons for poor grounding of the casing end shield are as follows:

(1) The wire is broken between the end shield and the lead post. The end shield and the lead post are connected by insulated wires. If the wire is broken, the end shield will fail to ground.

(2) Poor contact between the lead post and the grounding sleeve. The lead post and grounding sleeve are made of copper, and the grounding sleeve is sleeved outside the lead post. Under normal circumstances, the structure coordination ensures that the grounding sleeve and the lead post are of equal potential. If impurities exist in the end shield of the casing and are interspersed between the grounding sleeve and the lead post, it may cause poor contact between the lead post and the grounding sleeve, resulting in poor grounding of the end shield and a floating potential.

(3) Poor contact between the grounding sleeve and the grounding cover. The grounding cover is always reliably grounded during operation. The grounding cover is connected to the grounding cover by the spring pressure on the lead post. When the spring performance is normal, the grounding cover is in good contact with the grounding cover, ensuring good grounding of the casing end shield. If the performance of the spring is deteriorated or the spring is jammed, the spring will not rebound in place, and the grounding sleeve will not be in close contact with the grounding cover, resulting in poor grounding of the end shield.

3. Analysis of the cause of the failure
In this section, two failures will be combined to analyze the causes, characteristics and on-site treatment of the minor ablation and burning of the end shield of the capacitive casing.

3.1 Fault 1 (slight ablation of the end shield)
The bushing model of a 500 kV high voltage shunt reactor is BRDLW-550/630-4, which adopts a spring cap type end shield structure. One day, the maintenance personnel tested the reactor and found that there were obvious discharge traces at the end shield tap of the A-phase high voltage bushing and the end shield cover. They further tested the grounding condition of the end shield terminal and found that the terminal was poorly grounded. The discharge situation of the casing end shield is shown in Figure 3.

The end shield of the casing was disassembled on site, and dust was found in the contact parts of the grounding casing, lead post, and aluminum seat, which was preliminarily judged to be a residue
from low-heat discharge, as shown in Figure 4.

![Figure 3. Discharge traces on the end shield of the casing](image1)

![Figure 4. Dust accumulation in the end shield](image2)

After analysis, the reason for the failure of the bus hing end shield is that there are problems in the manufacturing process, resulting in poor contact between the lead post and the grounding cap, resulting in abnormal virtual grounding of the end shield, and long-term low heat discharge at the grounding of the end shield [4-5], which eventually leads to ablation of the end shield.

A new end shield was replaced on site and electrical tests were carried out on the casing and end shield, and the test results met the requirements of the test regulations. Observe that the color of the oil flow in the casing is normal, and sample the dissolved gas analysis in the oil. The test result meets the judgment of GBT 24624-2009 "Insulation casing oil-based insulation (usually paper) immersion medium dissolved gas analysis (DGA)). "Guidelines" requirements. The analysis results of dissolved gas in oil are shown in Table 1.

| Gas   | H2     | C2H2   | CH4   | C2H6   | C2H4 | THC | CO | CO2  |
|-------|--------|--------|-------|--------|------|-----|----|------|
| Value | 109.61 | 0.00   | 0.00  | 1.66   | 0.00 | 1.66| 479.8 | 479.8 |

After the defect of the end shield was eliminated, the power transmission of the reactor was restored, and the operation has been normal up to now. It can be seen that when the end shield is slightly ablated, the defects can be eliminated by replacing the end shield after confirming that the electrical test and oiling test of the casing are qualified, and there is no need to replace the casing.

### 3.2 Fault 12 (end shield burned)

One day, the maintenance personnel tested a 500kV high-voltage shunt reactor and found that there was obvious oil leakage at the end shield of the B-phase high-voltage bushing, and there was black carbon deposit in the leaked insulating oil. It was preliminarily judged that there might be inside the end shield. Discharge phenomenon. After opening the end shield cover, it was found that the insulating oil was leaking in an oil stream, as shown in Figure 5.
Figure 5. Oil leakage on the end shield

Sampling for dissolved gas analysis in oil, the test results did not meet the requirements of GBT 24624-2009 "Guidelines for the Judgment of Dissolved Gas Analysis (DGA) of Insulating Casing Oil as Primary Insulation (usually Paper) Impregnated Medium Casing". The analysis results of dissolved gas in oil are shown in Table 2.

|   | H2  | C2H2 | CH4 | C2H6 | C2H4 | THC | CO  | CO2 |
|---|-----|------|-----|------|------|-----|-----|-----|
|   | 5274| 3612 | 1447| 0    | 2167 | 7227| 2258| 1739|

Table 2 Fault 2 Analysis of Dissolved Gas in Oil μL•L⁻¹

After inspection, the end shield grounding device of the casing was seriously damaged, a large amount of residues existed in the capacitor core and could not be removed, and the casing could not be repaired on site. The failed casing was replaced with a spare casing. After the replacement, the failed casing was returned to the factory for diagnostic testing and disassembly inspection. The results are as follows:

(1) There are obvious ablation marks on the lead post of the end shield of the casing and the sheath cover. After removing the fixing bolts of the test tap shell of the end shield, it was found that the bottom sealing gasket and insulating parts had obvious ablation marks. When inspecting the end shield of the casing, it was found that the lead post was obviously loose, which could be shaken back and forth by hand, the lead post had obvious discharge and carbonization traces, the insulation pad had been severely burned (see Figure 6), the lead post and the internal lead were connected intact, and there was no virtual connection. (See Figure 7).
(2) Test the capacitance and dielectric loss of the main insulation of the bushing through the lead string, and the test results meet the requirements of the regulations.

(3) The outer sheath of the casing was removed, and it was found that the oil-paper insulating casing was smooth and normal. The casing oil-paper insulated capacitor core was disassembled, and no abnormal discharge traces were found (see Figure 8).

After analysis, the reasons for the internal discharge of the end shield are as follows:

The size of the steel pin used in the casing transfer test or the routine preventive test after it is put into operation does not match the pin hole. The steel pin produces burrs on the pin hole when inserting and removing, causing the grounding sleeve of the end shield to fail to rebound. Discharge occurs when in place.

After the casing capacitance, dielectric loss, and insulation resistance test, impurities are mixed in the grounding sleeve and the lead post of the end shield, resulting in discharge due to poor grounding.

In summary, after the failure of the end shield, the casing should be replaced immediately when it is determined that there is an abnormality in the casing electrical test and the oil chemical test.

3.3 Improvement measures

To sum up, it can be seen that the cause of discharge or oil leakage at the end shield of the casing is poor grounding of the end shield [6-9]. After research, adding a spring thimble inside the old end shield grounding cap can effectively improve the end shield grounding problem. The structure diagram and physical diagram of the improved grounding cap are shown in Figure 9 and Figure 10 respectively.
Pay attention to the following matters when replacing the grounding cap:

1. The spring thimble (shaft pin) in the grounding cap must be horizontally aligned with the lead post, keep close contact with the lead post, and cannot shift.

2. The length and elasticity of the spring in the grounding cap should be verified appropriately. The spring force should not only ensure good contact between the lead post and the thimble, but also prevent the insulator at the bottom of the lead post from being damaged. If the force on the lead post is too large, the insulation at the bottom of the lead post may be deformed or even damaged, causing oil leakage.

4. Conclusion

Based on the above analysis, it can be seen that due to poor process, component aging or improper maintenance, the spring cap type end shield may cause poor grounding of the end shield, cause floating discharge, and finally cause the failure of the bushing end shield. In order to ensure the safe and stable operation of the power grid, it is necessary to strengthen the operation and maintenance of the casing and improve the work. Suggestions:

1. During power outage maintenance, check the exit device of the casing end shield, focusing on checking whether there is discharge or oil leakage inside the end shield cover, and the dielectric loss, capacitance and ground insulation of the main insulation of the casing. The resistance is tested, and the problem should be dealt with immediately.

2. The maintenance test of the casing end shield should be performed strictly in accordance with the manufacturer's instructions to prevent improper operation from causing failure of the end shield device.

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