Influencing factors and countermeasure analysis of a 800kV coupling capacitor dielectric loss test

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Abstract. The coupling capacitor is installed on the AC bus side of the converter station for AC filtering to filter out a large amount of harmonics generated by the converter transformer during the AC-DC conversion process. Therefore, the reliability assessment test of its insulation status is of great importance to the safety and stability of the UHV power grid. In the UHV field test, the dielectric loss factor of the coupling capacitor is tested at a voltage of 10 kV and below, but the device itself has the Garton effect, and sometimes the abnormal data measured cannot truly reflect the insulation state of the device. The thesis analyzes the abnormality of the dielectric loss factor test data of 800kV coupling capacitors in UHV converter stations from the structure, use conditions and test methods of the equipment, and gives a detailed analysis of the causes of the abnormality. Recommendations for operation.

Keywords: Coupling capacitor, Garton effect, dielectric loss factor, countermeasure analysis

1. Introduction
The requirement of State Grid Corporation Enterprise Standard "(Q/GDW1168-2013) Regulations for condition maintenance of power transmission and transformation equipment" and "Regulations of condition-based maintenance & test for electric equipment", the dielectric loss factor of the coupling capacitor: film-paper composite is less than or equal to 0.0025, Oil-impregnated paper less than or equal to 0.005 (attention value). In the UHV field test, the dielectric loss factor of the coupling capacitor is tested under the voltage of 10kV and below, however, the device itself has the Garton effect, and sometimes the abnormal data measured cannot truly reflect the insulation state of the device. [12].

The coupling capacitor is installed on the AC bus side of the converter station and used for AC filtering to filter out a large number of harmonics generated by the converter transformer during the AC-DC conversion process. Therefore, the reliability evaluation test of its insulation condition has great effect on the safety and stability of the UHV power grid. Significant meaning. Aiming at the abnormality of the test data of the dielectric loss factor of the 800kV coupling capacitor in the UHV converter station, the paper analyzes the abnormal causes in detail from the structure, use conditions and test methods of the equipment, and gives the on-site implementation strategy and equipment to deal with the Garton effect of the equipment. Running advice.
2. Coupling capacitor electrical structure
The coupling capacitor is a single-column outdoor device, composed of 4 capacitor units stacked in series, and the outer insulation is a composite sleeve, from top to bottom: upper capacitor unit, middle upper capacitor unit, middle capacitor unit, lower capacitor unit, The next section capacitor unit is connected with the mounting base. The low voltage end of the capacitor is the outlet bushing on the side wall of the base, the high voltage end is the line terminal on the upper cover of the upper capacitor, and the base has a grounding fastener for grounding. The electrical schematic diagram of the capacitor is shown in Figure 1.

![Figure 1. Electrical schematic](image)

In the picture: A—high voltage C—capacitor N—low voltage

When the coupling capacitor is not used as a carrier for the communication interface, the N terminal must be directly grounded and cannot be opened. When used as a carrier for communication, its N terminal must be grounded through a combined filter.

3. The Test method and significance of dielectric loss
In the UHV field test, the positive connection method or other feasible methods are used to test the dielectric loss and capacitance of the capacitor. The test principle diagram is shown in Figure 2.

During the field test, the regularity of the system error should be eliminated to prevent it from becoming an influencing factor of the measurement result, such as electromagnetic interference. The outer surface of the porcelain sleeve of the coupling capacitor should be cleaned before the test. The coupling capacitor under test is converted at the same temperature, and the capacitance temperature coefficient is $-4 \times 10^{-4} \text{K}^{-1}$. The accuracy of the measuring equipment is not lower than level 1.

![Figure 2. Schematic diagram of dielectric loss factor test](image)
Note: 1. The measured voltage does not exceed 10kV.
2. Both the high voltage line and Cx test line should be suspended in the air and cannot touch the ground. For detailed wiring and operation methods, please.

Note that the test wiring contact contacts must be firmly connected, pay attention to the possible electromagnetic interference between the tested equipment and other equipment; pay attention to the weather conditions, the humidity is not more than 80%; taking into account the influence of the field test temperature, it must be recorded during each test. The ambient temperature on site at that time, or use an infrared thermometer to measure and record. When the test conditions of the tested product are generally the same, it is required that the difference between the measured capacitance of two consecutive times after temperature conversion does not exceed ±5%; the measured tanδ of the capacitor is ≤0.5%, if there is an abnormality, analyze and re-measure in time.

When the insulating medium of the coupling capacitor is in good condition, the dielectric loss factor tanδ will not increase significantly due to the increase of the voltage change; if there is an abnormal defect in the insulating medium, the tanδ will increase significantly with the increase of the voltage change.

4. The principle of the Garton effect
The Garton effect was discovered by Professor Garton M when he was thinking about studying the dielectric loss of oil-paper composite insulation. Relevant studies have concluded that the dielectric loss factor of the coupling capacitor is higher when the applied voltage is lower than when the higher voltage is applied. UHV field tests have found that the dielectric loss factor of the coupling capacitor is abnormal when the 10kV voltage is tested.

The ion distribution under different voltages is shown in Figure 3. When the AC voltage is relatively low, the ion movement speed in the coupling capacitor dielectric is relatively slow, and the distance that the impurities move is not far. Most of the ions cannot reach the surface of the insulating paper. The blocking effect is not large, and there is electric current in the positive and negative half cycle or full cycle of the voltage action, so the obtained dielectric loss factor is relatively large. However, when the alternating current increases, the intensity of the externally applied electric field increases, and the moving distance of the ions becomes farther. Most of the ions reach the surface of the insulating paper, and the blocking characteristic of the insulating paper becomes significant. The ions cannot continue to migrate, causing the current to flow. Termination. Even if the ion breaks through the barrier, due to its strong ion mobility, the movement time between the ion layers during the half cycle of the voltage alternating is very short, which reduces the dielectric loss factor. [9-11].

5. Analysis of 800kV coupling capacitor test example
In May 2020, testers conducted dielectric loss and capacitance tests on an 800kV coupling capacitor at a converter station. The coupling capacitor model is OAM620-0.005H, and the rated capacitance is 0.0052uF. The test data is shown in Table 1.
It can be seen from Table 1 that the value of the dielectric loss factor in section 4 of the coupling capacitor exceeds the regulatory requirements. In order to verify the influence of the Garton effect, the dielectric loss factors when the applied voltage is 10kV and 5kV were tested and compared.

| Installation location | Factory default $\tan \delta$ | Handover value $\tan \delta$ | 2018 Pre-test $\tan \delta$ | 2019 Pre-test $\tan \delta$ |
|-----------------------|-------------------------------|----------------------------|-----------------------------|-----------------------------|
| 1                     | --                            | 0.207                      | --                          | 0.160                       |
| 2                     | --                            | 0.213                      | --                          | 0.163                       |
| 3                     | --                            | --                         | --                          | 0.059                       |
| C                     | --                            | 0.204                      | --                          | 0.273                       |

Table 2. Comparison of dielectric loss factors at different voltages

| Test voltage | 5kV | 10kV |
|--------------|-----|------|
| Dissipation factor | 0.295% | 0.273% |

6. Preventive solution

6.1. Analysis of data abnormalities

1) In this type of capacitor unit, the capacitor element medium is full film and impregnant GRY620, both of which are polar media. After experimental research, the normal polarization current and polarization power of the medium do not increase with the increase of the test voltage, so it is lower. Under the test voltage, the ratio of the dielectric polarization current to the capacitance current is very high, so that the measured value of the dielectric loss is significantly higher than the dielectric loss limit under the rated voltage. At higher test voltages, the ratio of dielectric polarization current to capacitance current decreases significantly, so the measured value of dielectric loss decreases significantly.

2) Polarization loss is an inherent characteristic of the medium, which will not affect the operating performance and life of the capacitor product, and the dispersion of the polarization loss is relatively large, which is related to the state and time of the dielectric polarization during operation before the capacitor test.

3) The insulation performance is reduced due to the deterioration of the medium, and the measured value of the dielectric loss increases with the increase of the test voltage.

4) Clause 18.0.3-1 of GB50150-2016 "Electrical Equipment Handover Test Standard for Electrical Installation Engineering": The measured dielectric loss factor ($\tan \delta$) should meet the requirements of the product technical conditions.

5) During the factory test of the capacitor unit, refer to the test method of GB19749 "Coupling Capacitors and Capacitor Voltage Dividers", and measure at 0.9-1.1 times the rated voltage according to the provisions of the measurement procedure in clause 2.4.1.

6.2. Operation and maintenance recommendations

The film-paper composite coupling capacitor, although its preventive test data meets the requirements of relevant operating regulations, the migration of ions has increased. If there is a small amount of moisture in the coupling capacitor, it will affect the corrosion of internal accessories, thereby aggravating the increase of ion concentration, and will endanger the safety of equipment and power grid after long-term operation. If the ion movement of the coupling capacitor increases when the impregnant dissolves the equipment related accessories, this phenomenon will have a relatively small impact on the stable operation of the coupling capacitor. Therefore, strengthen infrared monitoring after putting it into operation, and analyze and deal with it in time when the temperature is abnormal.
Or after the next routine power failure, the dielectric loss factor measurement of the coupling capacitor should be completed within 5 hours of the power failure to eliminate the influence of internal stray ions on the measurement results under low voltage.

7. Conclusion
According to the abnormality of the test data of the dielectric loss factor of the 800kV coupling capacitor in the UHV converter station, the paper analyzes the abnormal reasons in detail from the structure, use conditions and test methods of the equipment, and draws the following conclusions:

1) The on-site operating conditions of UHV coupling capacitors are relatively loose. Coupling capacitors with abnormal test data can continue to operate, but infrared monitoring should be strengthened to find defects early. For previous experiments, the Garton effect of the coupling capacitor is obvious, and maintenance should be arranged.

2) If the dielectric loss factor is relatively large during the test, you can use several more pressure points to test separately, and finally make a correct judgment on the insulation defect or the Garton effect.

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