Analyze and Study on the Typical Operation Fault of Transmission Lines Composite Insulator

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ABSTRACT

As a vital part of transmission lines, the insulator's operation property has a good effect on the safety and reliability of high voltage power grid. Composite insulators have been applied extensively for its lightness and good antifouling characteristics. At present, 110kV transmission lines in Chengdu mountainous area are adopted composite insulator generally for its good antifouling properties. Therefore, it is important to focus on the change of composite insulator's properties for the reliable operation of transmission lines. Based on a typical example of composite insulator breakdown, this paper has analyzed the accident cause, tested the properties of composite insulators and pointed out the defects of tested composite insulators. The results showed that the hydrophobicity of composite insulator would be weakened in long operation with the affects of haze, which could result in the decreasing of insulation characteristic and causing flashover. To make sure the stable operation of transmission lines, this paper has pointed out some precautionary measures like live replacement of composite insulator, to prevent the operation fault of composite insulator.

***KEYWORDS*：Transmission lines, Operation property, Composite insulator, Precautionary measures**

0 introduction

Insulator is an important part of transmission lines, and its property has a good effect on the stable operation of power transmission lines. Composite insulator has been wildly used for its good antifouling property[1-2], which mainly depends on peculiar hydrophobicity and hydrophobic mobility of the silicone rubber material[3-4]. The advantages of composite insulator are high strength, light weight, small volume, easy to install, convenient operation maintenance, and without impurity cleaning and zero valuation. Long time operation experience shows that the silicone rubber composite insulator can avoid the pollution flashover accident effectively.

However, with the growth of composite insulators operation time, silicone rubber material will age gradually with the impact of surrounding environment, leading to hydrophobicity declined. Recent two years, The haze weather has become more and more serious in China, which further increases the complexity of composite insulators operation environment[5-7], and gradually becomes one of the reasons of hydrophobicity reduced. The so-called haze is a combination of frog and haze, which means a large number of very fine dust particles and other dry substances are suspended in air in addition to suspended freedom drops, muddying the air. When haze occurs, it will increase the contamination of composite insulators surface, and the moisture will make the surface grime wet. Therefore, the haze can be called as "foul fog."

Based on a typical example of 110kV composite insulator flashover accident, this paper has analyzed the detection characteristics of composite insulators, and studied deeply the defects and problems of composite insulators in the long run. The results showed that the hydrophobicity of composite insulators would be decreased for aging of silicone rubber. While haze humid weather occurs, it will produce a lot of space charge, and its derivative electric field will has an influence on the gap field with external electric field, which results in the dielectric strength of interpolar air gap weakened, leading to breakdown, and causing flashover tripping.

1 Property tests of fault insulator

June 23, 2015, an unexplained fault tripping occurred on 110kV Huitie transmission line 117# tower phase C, reclosing successfully. The model of fault insulator is FXBW-110. When the tripping occurred, the weather was drizzled with temperature between 23℃ and 28℃, and the relative humidity is 94%. Aiming at this composite insulator fault, this paper has accurately estimated the cause of insulator breakdown, and tested the property of insulator. Test standard referenced GBT 19519-2014 "Definition, test methods and acceptance criteria of suspension and tension composite insulators for nominal voltage greater than 1000V AC system ".

1.1 Selection of samples

The test selected two 110kV Rod Composite Insulators with similar operation time and deterioration as research subjects, and the insulator type was FXBW-110. The samples included 110kV Huitie transmission line 117#tower phase C composite insulator (sample A) and 110kV Huitie transmission line 117#tower phase A composite insulator (sample B). Visual inspection showed that two samples had surface natural contamination attachment with different levels. There was no sign of physical damage and creeping discharge on the surface of connection fittings and umbrella skirts, and the appearance was intact.

1.2 Power frequency dry and wet flashover tests

To verify whether the permanent discharge channel of fault insulator was formed in the flashover process, which could lead to electrical performance decreasing, first of all, dry and wet flashover voltage of tests have been implemented, as figure 1 showed.

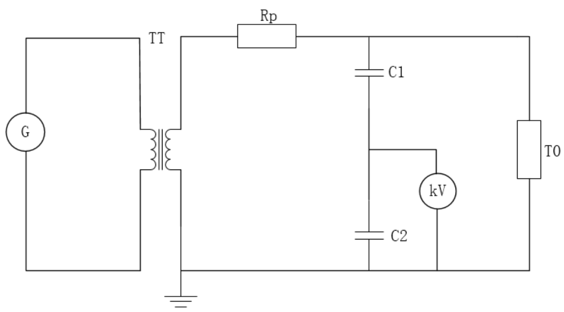


Fig. 1 Circuit diagram of flashover（R_p is the protective resistance, T_0 is the sample）

Two samples were both cut to 1000mm insulation distance from high voltage side, and carried out dry and wet flashover tests five times. The results are shown in Table 1 and Table 2.

Tab. 1 Power frequency dry flashover tests

Flashover(kV)	Sample	
	A	B
1	368.0	364.0
2	367.9	362.1
3	363.8	360.1
4	367.2	368.4
5	367.0	356.0
Average(kV)	366.8	362.1
Correction(kV)	379.7	370.2

Tab. 2 Power frequency wet flashover tests

Flashover(kV)	Sample	
	A	B
1	347.8	357.1
2	349.5	353.5
3	341.3	354.0
4	341.8	348.0
5	336.7	353.5
Average(kV)	343.4	353.2
Correction(kV)	350.4	358.6

Experimental data shows that frequency dry flashover voltage are between 370kV and 380kV for 1000mm length insulator, which is much higher than the normal operating voltage (110kV), and the dispersion of flashover voltage data is good. The difference of dry and wet flashover voltage for sample A and B are 3.1% and 7.7% respectively, less than the 20% specified value, indicating that the electrical performance of samples is restored after flashover. Therefore, the possibility of electrical performance degradation because of flashover is excluded.

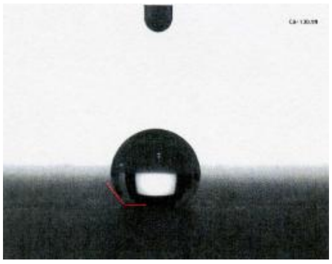
1.3 Hydrophobicity tests

The hydrophobicity tests have been carried out based on GB/T24622-2009 standard. This paper has used contact angle method and the spray method to confirm the hydrophobicity of insulators.

1.3.1 General hydrophobicity test

Tab. 3 General hydrophobicity test

Sample	A1	A2	A3	A4	A5	Specified value
Grade of HC	HC3	HC3	HC3	HC3	HC4	HC1 to HC2, and the amount of HC3 less than 1
θ_{av} (°)	131	130	130	/	/	≥100
θ_{min} (°)	128	128	127	/	/	≥90
Sample	B1	B2	B3	B4	B5	Specified value
Grade of HC	HC3	HC3	HC3	HC3	HC3	HC1 to HC2, and the amount of HC3 less than 1
θ_{av} (°)	133	133	133	/	/	≥100
θ_{min} (°)	129	131	130	/	/	≥90



Angle picture about general hydrophobicity test of sample A1

HC grade picture about general hydrophobicity test of sample A1

Angle picture about general hydrophobicity test of sample B1

HC grade picture about general hydrophobicity test of sample B1

Fig. 2 The pictures of general hydrophobicity test

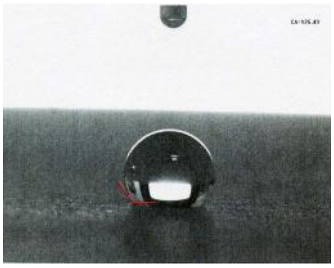
Five umbrella cover material were excised from sample A and B respectively. The materials were washed with ethanol and distilled water, and samples were kept in a lab environment for 24h after dried. The hydrophobicity results are shown in table 3 and figure 2.

1.3.2 Hydrophobicity weakened test

Immersed the samples in distilled water for 96h after the hydrophobic test in a laboratory environment. Then took out the samples, shook off the surface water and soaked up the residual moisture with filter paper, and tested the hydrophobicity within 10min. The results were showed in table 4.

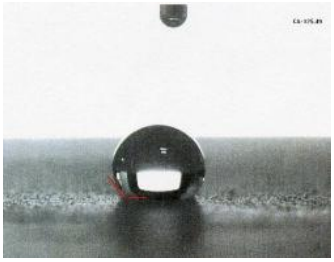
Tab. 4 Hydrophobicity weakened test

Sample	A1	A2	A3	A4	A5	Specified value
Grade of HC	HC6	HC6	HC6	HC6	HC7	HC3 to HC4, and the amount of HC5 less than 1
θ_{av} (°)	126	128	124	/	/	≥90
θ_{min} (°)	123	125	122	/	/	≥85
Sample	B1	B2	B3	B4	B5	Specified value
Grade of HC	HC5	HC6	HC6	HC5	HC6	HC3 to HC4, and the amount of HC5 less than 1
θ_{av} (°)	133	133	133	/	/	≥90
θ_{min} (°)	129	131	130	/	/	≥85



Angle picture about hydrophobicity weakened test of sample A1

HC grade picture about hydrophobicity weakened test of sample A1



Angle picture about hydrophobicity weakened test of sample B1

HC grade picture about hydrophobicity weakened test of sample B1

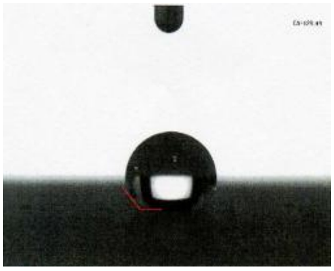
Fig. 3 The pictures of hydrophobicity weakened test

1.3.3 Hydrophobicity recovered test

Absorbed the surface water of samples with filter paper after the hydrophobicity weakened test, and kept them in a laboratory environment for 48h, then tested the hydrophobic properties.

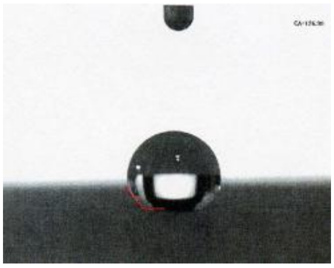
Tab. 5 Hydrophobicity recovered test

Sample	A1	A2	A3	A4	A5	Specified value
Grade of HC	HC3	HC4	HC3	HC4	HC4	HC2 to HC3, and the amount of HC4 less than 1
θ_{av}（°）	126	128	124	/	/	≥95
θ_{min}（°）	123	125	122	/	/	≥90
Sample	B1	B2	B3	B4	B5	Specified value
Grade of HC	HC4	HC3	HC4	HC3	HC3	HC2 to HC3, and the amount of HC4 less than 1
θ_{av}（°）	127	127	126	/	/	≥95
θ_{min}（°）	125	126	124	/	/	≥90



Angle picture about hydrophobicity recovered test of sample A1

HC grade picture about hydrophobicity recovered test of sample A1



Angle picture about hydrophobicity recovered test of sample B1

HC grade picture about hydrophobicity recovered test of sample B1

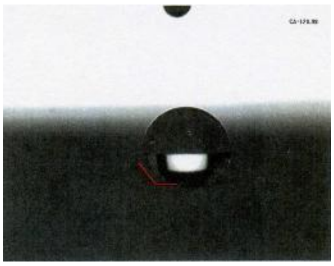
Fig. 4 The pictures of hydrophobicity recovered test

1.3.4 Hydrophobic mobility d test

Brushed the samples surface with artificial contamination of $0.1mg/cm^2$ salt density and $0.5mg/cm^2$ ash dense after the hydrophobic test, and placed them in a laboratory environment for 96h, then tested the hydrophobic mobility properties.

Tab. 6 Hydrophobic mobility test

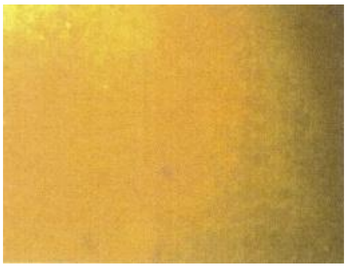
Sample	A1	A2	A3	A4	A5	Specified value
Grade of HC	HC7	HC7	HC7	HC7	HC7	HC2 to HC3,and the amount of HC4 to HC5 less than 1
θ_{av} （°）	131	129	132	/	/	≥110
θ_{min} （°）	128	127	130	/	/	≥100
Sample	B1	B2	B3	B4	B5	Specified value
Grade of HC	HC7	HC7	HC7	HC7	HC7	HC2 to HC3,and the amount of HC4 to HC5 less than 1
θ_{av} （°）	134	130	130	/	/	≥110
θ_{min} （°）	131	128	127	/	/	≥100



Angle picture about hydrophobic moblity test of sample A1

HC grade picture about hydrophobic moblity test of sample A1

Angle picture about hydrophobic moblity test of sample B1



HC grade picture about hydrophobic moblity test of sample B1

Fig. 5 The pictures of hydrophobic mobility test

According to the above hydrophobicity tests, it can be seen that the hydrophobic grades of sample A (fault insulator) and sample B (non-fault insulator) are HC3 level, and most hydrophobic grades are HC6 in hydrophobicity weakened test. The hydrophobic grades are HC3 to HC4 in hydrophobic recovery test, and the hydrophobic grades of samples are HC7 in the hydrophobic mobility test, which are much higher than the specified value. It points out that hydrophobic properties of sample A and B are significantly reduced compared to normal composite insulators, and the hydrophobic mobility is almost completely lost.

2. Analysis of flashover cause

Failure analysis report shows that the insulator flashover occurred at 5:00 am, and weather was drizzle. The PM2.5 index was 200μg/m3, which meant the haze pollution was severe. The effects of haze to composite insulators can be explained in two ways. Firstly, all kinds of particles in haze will increase the amount of composite insulator surface contamination. Secondly, haze may cause the composite insulator surface moist, which could increase leakage current, resulting in creeping discharge.

Through the comparative tests between fault and non-fault insulators in electrical and material properties. It can be seen that the electrical properties do not decrease significantly after flashover. However, after a long-running the hydrophobicity has declined seriously and the hydrophobic mobility has almost lost. Combining with weather and humidity conditions, the reason of flashover can be considered that the air gap was breakdown in low temperature and high humidity after the hydrophobicity had been reduced.

The pollution flashover voltage of composite insulator is higher because its umbrella skirt material has good hydrophobicity and migration. Hydrophobic migration and recovery performance are main indicators of the operating insulators, which will be gradually weakened over time, and become worse at lower temperature environment. Under prolonged fog condition, the air is humid, resulting in the decrease of insulator surface resistance and the increase of contamination conductivity. With severe air contamination and the serious loss of hydrophobicity, the space charge from creeping discharge of insulator and the ionization of suspended atmospheric contamination particles dissolved in water will form derived electric field, promoting the development of leader and steamer in air gap, causing the distortion of insulator string surface electric field distribution. Then the dielectric strength of inter-electrode air gap would decrease, which would result in flashover by puncture of air nearby the insulator. However, the water in discharge passage would quickly evaporate for the heat from flashover, losing the humidity condition to continue the air gap discharge. Therefore, the dielectric property of insulator would soon recover from the flashover, making reclosing successful. Thus, there is no obvious discharge trace on the insulator surface because of air gap breakdown.

3. Conclusion

This paper has analyzed the reason of transmission line breakdown in terms of composite insulators electrical and material properties. It turns out that the important factors of insulator flashover are degradation of hydrophobicity and severe haze weather. Therefore, aiming at old and over operation composite insulators, prevention measures such as live replacement of insulators and UV imaging detection should be adopted to avoid the deterioration of insulators and ensure the security and stability operation of transmission lines.

4. Reference

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