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Flashover characteristics of plastic cloth on ±800 kV HVDC transmission line

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Flashover characteristics of plastic cloth on ±800 kV HVDC transmission line

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Abstract. In order to study the reasons for the restart failure after locking of the ±800kV HVDC transmission lines caused by the plastic cloth of the greenhouse, combined with a bipolar closure fault example of the ±800kV HVDC transmission line caused by a plastic cloth, the voltage and current time characteristics of the ±800 kV HVDC transmission line after failure are obtained through fault field investigation and fault recording analysis. Through plastic cloth contamination detection and linear equivalent test of ±800kV DC tolerance voltage, the necessary conditions for flashover and the time level of local burning to whole cloth breakage are obtained. The flashover, combustion and deionization process of plastic cloth are showed through linear equivalent 800kV DC voltage flashover test, which proves the possibility of three restart failure owing to the insufficient deionization as a result of the fact that fault current is large, the discharge channel is dispersed and the restart interval is short. Meanwhile, the flashover characteristics of plastic cloth of ±800kV HVDC transmission lines are obtained.

1. Introduction

With the rapid development of China's economy and society, illegal building and tree planting as well as other activities in the power line protection area invade the transmission line passage. Even worse, some power towers are enclosed by the logistics center, warehouse, factory buildings, residential areas and all kinds of machinery construction. Therefore, the original line design standards can not satisfy the current situation. Discharge often occurs, which not only affects the safety of the power grid, but also poses a serious threat to the safety of the construction personnel [1-4]. In addition, infrastructure traffic construction has speeded up obviously, meantime,vegetable plastic greenhouse and steel structure greenhouse have been popular in large areas.The number of temporary slab houses has increased, which also increases the possibility of external force damage.

The main reasons of line tripping of 66kV and above transmission lines in a power grid company are as follows: lightning strike (1019, 43.2%), external force damage (784, 33.2%), bird damage (313, 13.3%), wind damage (114, 4.8%) and ice damage (40, 1.7%). The main causes of outage are as follows: external force damage (436, 54.5%), lightning strike (164, 20.4%), wind damage (93, 11.6%), bird damage (29, 3.6%) and ice damage (22, 2.7%). It can be seen that external force damage has become the main cause of transmission line tripping. At the same time, line tripping due to external force damage with low recombination power, is the primary cause of transmission line failure outage [5-9]. For 500 kV and above transmission lines, 55 trips were caused by external force damage. The main cause of external force damage in this year was foreign body short circuit, accounting for 61.8% of the total external force damage. Conductive or non-conductive objects hanging on wires are liable to cause short-circuit or phase-to-ground short-circuit. Suspended balloons, kites hanging on transmission lines, high-altitude parabolic can lead to short-circuit foreign bodies.

There are many vegetable greenhouse growers in Shandong Province. Shouguang is a famous greenhouse vegetable planting county and a top 100 economic County in China. The vegetable planting area has reached more than 800,000 mu. There are more than 300,000 vegetable greenhouses of various types. Plastic greenhouse cloth is often blown to the wire by wind. Plastic cloth in greenhouse seriously affects the safe operation of the power grid and affects the transmission, which poses a great threat to the safe operation of roads.

2. Fault profile

There was a bipolar blocking fault on a ±800kV DC transmission line. Pole I and pole II's traveling wave protection of A, B and C phases and sudden change protection acted, subsequently ,two full voltage and one half voltage restart failed. The electricity was resumed about 3 hours later. Inspectors found a piece of burned plastic cloth under a tower. According to the scene investigation, the owner of the shed reported that a 25-meter plastic cloth was torn by the wind and rolled up the wire. The plastic cloth fell to the ground after hearing the abnormal sound. The surface of the plastic sheet is wet and 25 meters long (22.9 meters apart from pole I and pole II). Discontinuous burns can be seen at both ends and in the middle, accounting for about a quarter of the total length. The greenhouse is a four-storey structure.From bottom to top, it is greenhouse support, the first layer of plastic cloth, thermal insulation cloth (not waterproof), the second layer of plastic cloth, which is used for rainproof. The second layers of plastic sheeting were scraped on the wire. The weather in the fault area is fine and the temperature is 7 ~ 19℃. When the fault occurs, a strong whirlwind is blown. The wind force is 6 ~ 7 level. There is rainfall two days before the fault. Figure 1, Figure 2 and Figure 3 show the site information.

Figure 1. Plastic cloth of fault field.

Figure 2. Fault pole tower and surrounding environment.

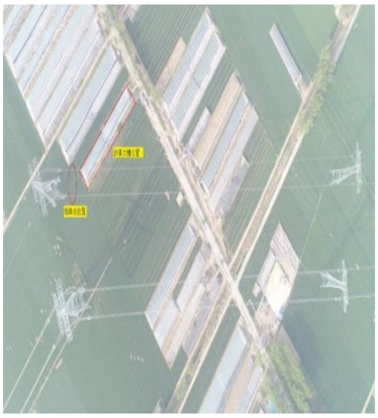


Figure 3. Aerial photograph of the fault pole tower.

The fault tower type is J30103A-39, the strain insulator-string is a four-joined 550kN disc insulator, and the jumping string is a double V series 160 kN composite insulator. The conductor type is 6×JL1/G3A-1250/70 and the pole space is 22.9 meters. The ground wire is erected on both sides, LBGJ-150-20AC aluminum clad steel wire on the left and OPGW-150 cable on the right. Nominal height is 39m while turn angle is 42° 41.Design meteorological zone is IV level and design wind speed is 27m/s. The line is north-south, and the topography is plain. The fault tower is located in a large area of farmland. There are no tall trees and buildings under the line or in the protection area. The area is a vegetable producing area with dense vegetable greenhouses.

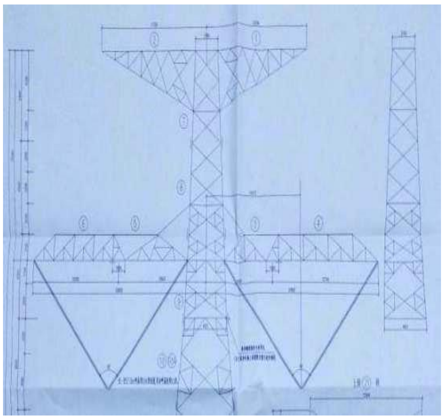


Figure 4. Single line map of J30103A-39 tower type's cross arm.

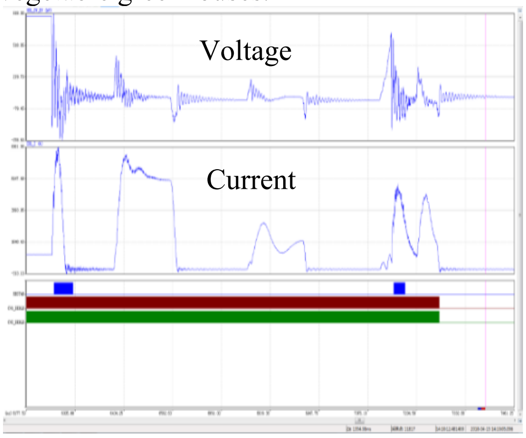


Figure 5. Pole I protection fault recorder arm.

The fault recorder diagram of pole I shows that the maximum fault current is 8.27 kA, the fault-to-latch time is about 35 ms, the first full voltage restart is 150 ms after the protection action, the system voltage rises to 421 kV, and the short-circuit current is 7.78 kA. The second full-voltage restart occur after 200 ms, subsequently the system voltage rises to 191 kV and the short-circuit current is 3.13 kA. Third half-voltage restart occur after 200 ms, and the system voltage rises to 639 kV, meantime the short-circuit current is 5.72 kA. Pole II restart process is the same as that of the Pole I.

The direct cause of the faults is that the faults are located in the plain area. Vegetable greenhouses in the protection area are dense under the line. Due to the heat collection effect of the greenhouse, a micro-meteorological area is formed, and a strong cyclone is produced in a short time. The plastic cloth of the greenhouse is broken and about 25 meters long plastic cloth is blown to the conductors of pole I and pole II by the wind. Wet broad plastic cloth insulation strength is low, resulting in short circuit.

There may be two reasons for the failure of the three restarts: one is that the plastic cloth short connector is not immediately burned, and the insulation between the poles is not fully restored, which may lead to the failure of the restart; the other is that the DC line restart time is short, and deionization is insufficient, which may lead to the failure of the restart. Therefore, it is necessary to study the mechanism of tripping failure caused by plastic cloth of greenhouse, and further clarify the reasons for restart failure, so as to provide guidance for the prevention and control of foreign matter on the line.

3. DC voltage withstand test

3.1. Contamination detection of plastic cloth on site

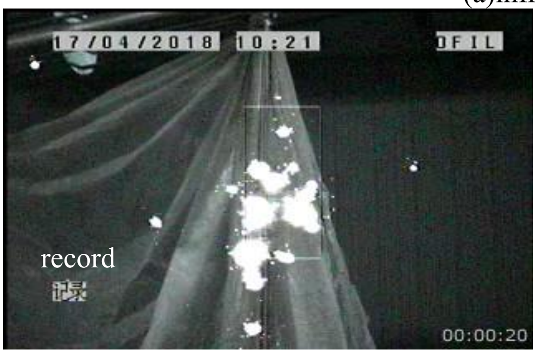
Take the plastic cloth in the field for contamination measurement, and the results shows that the surface equivalent salt density of plastic film in greenhouse is very low, with an average of 0.0013mg/cm^2, and the ash density is 0.0091~0.0117mg/cm^2, with an average of 0.0102 mg/cm^2. There is no significant difference between the two sides. It shows that the surface of plastic cloth is less polluted and the surface conductivity is smaller.

3.2. DC withstand voltage test of plastic cloth in plastic shed

In order to simulate the condition of discharge ablation of plastic film in greenhouse when faults occur, DC withstand voltage test is carried out on another plastic cloth in the same greenhouse. The test equipment used is +1600kV/30mA DC voltage generator, which can generate 1600kV voltage and the equipment capacity is 85kVA. The test length of plastic cloth in greenhouse is 11.5m (50% electrode space), the width is 5.5m, and the voltage is + 800 kV, - 800 kV, respectively. The test environment temperature is 20℃ and the relative humidity is 35%. The DC generator and the layout of the test are shown in Figure. 6.

Figure 6. DC voltage generator and test layout.

(a)infrared spectrum



(b)+800kV Ultraviolet spectrum

(c)-800kV Ultraviolet spectrum

Figure 7. Infrared and ultraviolet imaging of plastic cloth of original state.

In the first stage, DC resistance test of plastic cloth in the original condition is carried out. After hanging for one hour, the surface of the sample is dried and maintained for 2 minutes at ±400kV, ±500kV, ± 600kV, ± 700kV, ± 800kV, respectively. The discharge is observed and measured by infrared and ultraviolet spectroscopy. There is slight corona discharge sound when the voltage is up to

±800kV and the maximum temperature rise is 25.4℃. The ultraviolet spectrum shows that the discharge phenomenon of -800kV is stronger than that of + 800kV.

In the second stage, DC resistance test is carried out after spraying 2.5kg deionized water on plastic sheets in plastic shed. Obvious discharge occurs when the voltage is up to -400 kV. When the voltage is up to -750 kV, the test current is greater than the current setting value of the test equipment and the protection action is taken. Infrared imaging (Figure.8) shows a maximum temperature rise of 85℃, and ultraviolet imaging (Figure.9) shows a strong discharge. The discharge and heating locations are mainly located in the folds of plastic cloth.

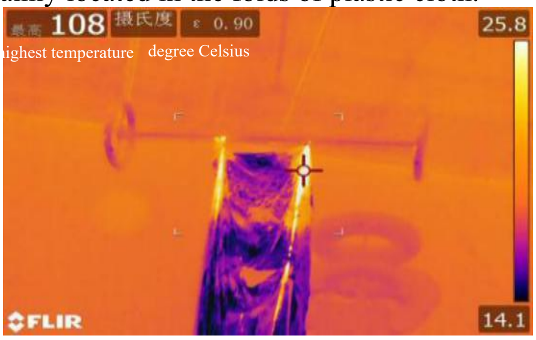


Figure 8. Infrared imaging of wet plastic cloth.

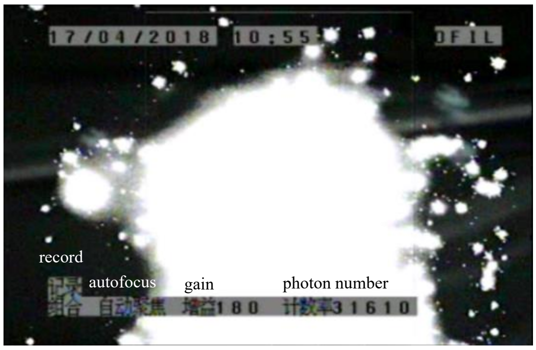
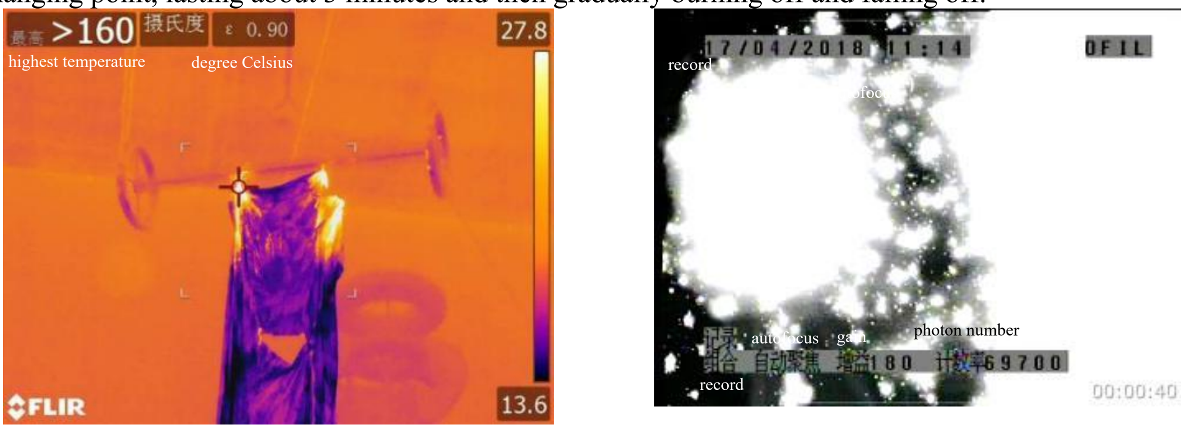


Figure 9. Ultraviolet imaging of wet plastic cloth.

In the third stage, DC tolerance test is carried out after spraying deionized water 1.5kg in the upper 3m area of plastic cloth. There is a sharp discharge phenomenon and protection acted when the voltage rises to -370kV. As can be seen from Figure.10, the maximum temperature rise is greater than 160℃, the ultraviolet imaging shows intense discharge happens, and the plastic cloth starts to burn from the hanging point, lasting about 3 minutes and then gradually burning off and falling off.



(a)infrared spectrum (b)Ultraviolet spectrum

Figure 10. Infrared and ultraviolet imaging of plastic cloth in the third stage.

From the above three stages of DC withstand test results, it can be concluded that: (1) plastic cloth of greenhouse can maintain a good insulation state under relatively dry conditions, and no obvious discharge occurs under normal operating voltage; (2) under the condition of moisture on the surface of plastic cloth, even if the surface equivalent salt density is very low, its insulation performance will be greatly reduced. Strong discharge occurs when the voltage is lower than the normal operating voltage; (3) plastic cloth of greenhouse has a large width, and there will be many folds. Electric field distortion and moisture concentration in the folds will easily lead to partial discharge and form multiple discharge channels; (4) for wet, wide and wrinkled plastic cloth of greenhouse, plastic cloth from partial combustion to whole distribution breakage takes minutes.

3.3. DC voltage flashover test

Another plastic cloth, 19.4m long, 6m wide and 11.5m pole spacing, is selected from the same greenhouse at the fault point. DC voltage flashover test is carried out after wetting. Deionized water is used to moisten the plastic cloth and the water consumption is 8.5L. Add the DC voltage to the wetting plastic until the flashover. The test layout is shown in Figure 11.

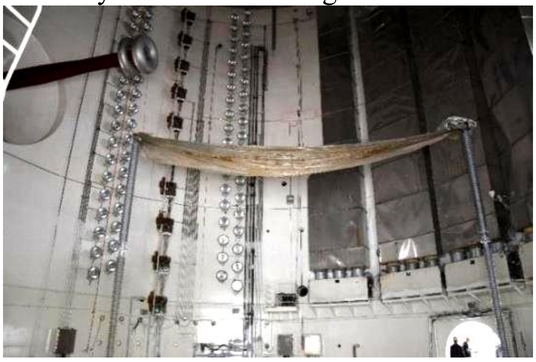
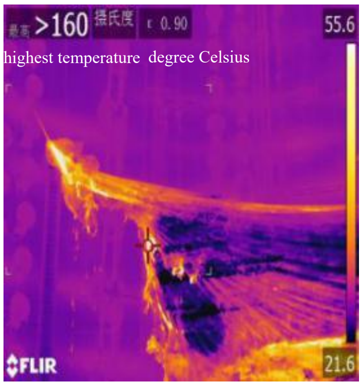
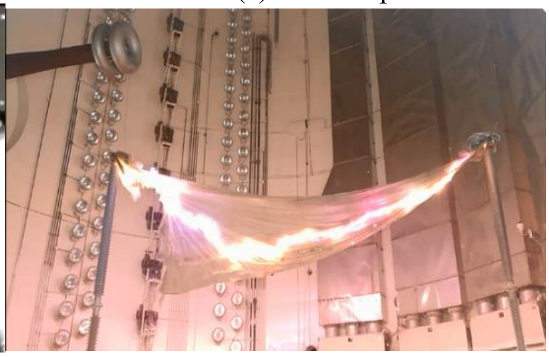


Figure 11. DC voltage flashover test layout.



(a)local arc (b)burning plastic cloth (c)infrared spectrum



(d)Ultraviolet spectrum (e)high speed video record of plastic cloth

Figure 12. DC flashover test of plastic cloth.

During the process, the local arc appears near the high-voltage end of the plastic cloth. The plastics layout obviously heats up and starts small-scale combustion. The infrared spectrum has obvious hot spots. From figure. 12 (c) ,UV spectrum has violent discharge phenomenon. When approaching the flashover voltage of 640kV, whole arc of the plastic cloth appears from high voltage end to the ground end. After the gap breakdown, the plastic cloth near the high-voltage electrode continues to burn, the combustion is not intense, but doesn't extinguish naturally. The above test results show that the intense discharge at flashover moment is not enough to cause the break of plastic cloth. After the discharge, the plastic cloth will continue to burn. Finally, the plastic cloth may break, separating from the conductor and even falling to the ground completely. This is consistent with the situation found by the inspectors But the process lasts for about 10 minutes.

4. Conclusions

Plastic cloth in greenhouse has high insulation strength under dry condition, which can withstand working voltage and will not cause flashover between poles. Under damp condition, the discharge of plastic part is enhanced, and the leakage current increases, so it is easy to form surface discharge. The DC flashover voltage of wet plastic plastic cloth is -640kV, which is about 80% of the normal operating voltage.

In the laboratory simulation test, the de-ionization time of the arc after flashover is about 160ms. Although the de-ionization time is less than 200 ms in the second and the third restart, the short-circuit current in the field is far greater than the short-circuit current in the test, and the insufficient de-ionization may still exist, resulting in the failure of three restarts.

Arc drift, scattered discharge channel formed by multiple folds, short restart time and other factors lead to the wet plastic cloth continuous short-circuit gap after the fault, and finally three restarts fail and bipolar block fault occurs.

References

[1] Hu Yi 2007 Analysis and prevention of transmission line operation faults [J] *High voltage technology* **33 (3)** 1-8

[2] Sheng Ge, Jiang Xiuchen, Zeng Yi, et al. 2007 Integrated monitoring and evaluation system for operation and failure of overhead transmission lines [J] *High voltage technology* **33 (8)** 183-186

[3] Hu Yi 2005 Problems and countermeasures affecting the safe operation of power grid [J] High voltage technology **31 (4)** 77-78

[4] Lu Jiazheng, Zhou Tejun, Wu Chuanping, et al. 2016 Statistics and analysis of 220kV and above transmission line faults in a provincial power grid [J] *High voltage technology* **42 (1)** 200-207

[5] Hu Yi, Liu Kai, Wu Tian, et al. 2014 Analysis and preventive measures for influencing factors of operation safety of transmission lines [J] *High voltage technology* **40 (11)** 3491-3499

[6] Song Delong, Luo Yuanping 2006 Characteristics of bird dropout flashover faults on HV transmission lines and preventive measures [J] *High voltage technology* **32 (5)** 122-123

[7] Peng Xiangyang, Qian Guanjun, Li Xin, et al. 2012 Intelligent diagnosis of tripping fault for overhead transmission lines [J] *High voltage technology* **38 (8)** 1965-1972

[8] Guo Xiuhui, Li Zhiqiang, Qian Guanjun 2005 New measures for shielding failure of transmission lines [J] *High voltage technology* **31 (7)** 37-38

[9] Gong Jiangang, Bao Jianqiang 2001 Test and analysis of power frequency flashover of composite insulators in Zhejiang for unknown reasons [J] *High voltage technology* **27 (5)** 70-71