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Study on Aging of Composite Insulators and Anti-Contamination Flashover Coatings in Fujian Province

Xinyuan WAN[a], Yunxiang CHEN[a], Deyuan LIN[a], Xiaojian XIA[a], Shengxiang LUO[a] and Yanqiong SHAO[b1]
[a] *Fujian Power Co., Ltd. Electric Power Research Institute, Fuzhou 350007, China*
[b] *College of Materials Science and Engineering, Fuzhou University, Fuzhou 350108, China*

Abstract. As an important part of transmission lines, composite insulators are susceptible to aging and failure due to contamination, UV and other factors during operation, leading to flashover accidents. This paper studies the aging characteristics of composite insulators and anti-pollution flashover coatings operating in coastal areas of Fujian province with different ages. The physical and chemical properties were characterized by fourier transform infrared spectroscopy (FTIR), scanning electron microscope (SEM), water contact angle (WCA) and volume resistivity. The results show that the content of Si-O bond and Si-CH_3 bond, hydrophobicity and surface roughness can be used to evaluate the aging degree of insulators.

Keywords. Composite insulators, anti-pollution flashover coatings, aging

1. Introduction

The composite insulator is mainly composed of high temperature vulcanized silicone rubber umbrella skirt sheath with external insulation protection and epoxy glass fiber core rod with internal mechanical support [1-3]. Compared with traditional porcelain insulators and glass insulators, silicon rubber materials have unique hydrophobicity and hydrophobicity mobility, and composite insulators show unique anti-pollution flashover performance. At the same time, because of their advantages of light weight and zero value, silicon rubber composite insulators have been widely used in overhead transmission lines of various voltage levels [4-8].

Silicone rubber material is a kind of organic polymer composite materials, composite insulator in complex outdoor environment operation, receiving, ozone, ultraviolet ray, filthy, discharge the bird pecked the influence of various factors, such as the sheath of silicon rubber umbrella skirt will fade, crack, tear, pulverization degradation phenomenon [9-14], such as the influence on the performance of the composite insulator insulation, Composite insulators with reduced insulation performance are more likely to appear surface erosion under severe weather conditions during grid operation, which further aggravates the aging of composite insulators and

[1] Corresponding author, Yanqiong SHAO, College of Materials Science and Engineering, Fuzhou University, No. 2 Xueyuan Road, New District, Fuzhou 350108, China. E-mail: 815257998@qq.com
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further reduces the insulation performance, thus bringing huge hidden dangers to the safe and stable operation of power grid [15-17].

Room temperature vulcanized silicone rubber (RTV) has excellent hydrophobicity and hydrophobicity mobility, which can significantly improve the pollution flashover resistance of electric porcelain or glass insulator [18]. Coating RTV on the surface of ceramic or glass insulators can significantly improve their anti-pollution flashover capability. But RTV coating, as an organic material, also has the problem of aging. Affected by environmental factors and the long-term effect of pollution, the RTV coating surface appears discoloration, pulverization, peeling and other phenomena, and the hydrophobicity is also reduced [19-21]. The hydrophobicity of RTV coating directly affects the anti-pollution flashover performance of RTV coating.

This paper studies the aging characteristics of composite insulators and anti-pollution flashover coatings operating in coastal areas of Fujian province with different ages. The main analysis methods used in this paper include Fourier Transform infrared spectroscopy (FTIR), Water contact angle (WCA), etc., and the relationship between some aging characteristics and material microscopic parameters is established to reflect the performance index relationship of silicone rubber.

2. Result and Discussion

The composite insulator samples studied in this paper are from 110kV Xucuo substation. The sample operating for 4 years is marked as “1”, operating for 16 years is marked as “2”. RTV coating is newly prepared. The surface condition of no.1 insulator is that the mandrel is seriously eroded and cracked, and the surface is seriously aged. A crack groove is formed and the crack is black. The skirt was also severely corroded, and perforated near the mandrel. Some of the skirt was notched, and the corroded part was connected into paths running through multiple skirts, seriously affecting the insulation performance of the string of insulators. The whole umbrella skirt of No. 2 insulator is intact, and the core rod has no obvious corrosion, which is used as the contrast of No. 1 insulator.

Composite insulator umbrella skirt materials or RTV will suffer from aging problems of varying degrees during operation, including main chain fracture of silicone rubber, decrease of crosslinking degree and reduction of methyl group in side chain, which will lead to the decline of electrical and mechanical properties of insulators. FTIR analysis was used to study the functional groups and chemical bonds of aged insulators. The WCA can effectively study the hydrophobicity change of silicone rubber surface to judge its aging degree and provide strong evidence for the continued application of composite insulator or RTV coating.

The micro morphology of the samples was observed by SEM (SUPRA55, Zeiss, Germany). It can be seen from Figure 1 that the surface of the newly prepared RTV is smooth. However, after 4 years, the surface of insulator becomes rough and holes begin to appear. After 16 years of running, a large number of holes and pulverization occurred

on the surface of insulators. This shows that the aging degree increases with the increase of running time.

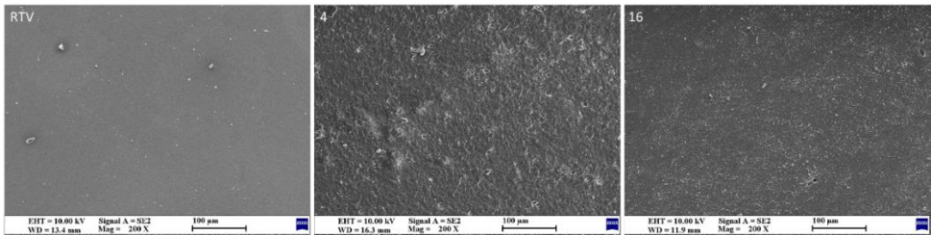

Figure 1. The micro morphology of RTV and insulators.

During the operation of insulator, the external surface mainly contacts with the outside world. We use XPS (K-Alpha+, Thermo Fisher, USA) to analyze the composite of RTV and insulators. The typical XPS spectrum is shown in Figure 2. It can be seen from the result that the samples mainly composed by C, Si, O and Al. and the main element composition of the sample is shown in Table 1. It can be seen from the results that with increasing the running time, the content of C on the sample surface decreases, and the content of O and Si increases. It is worth noting that the Al content decreases greatly with the occurrence of degradation.

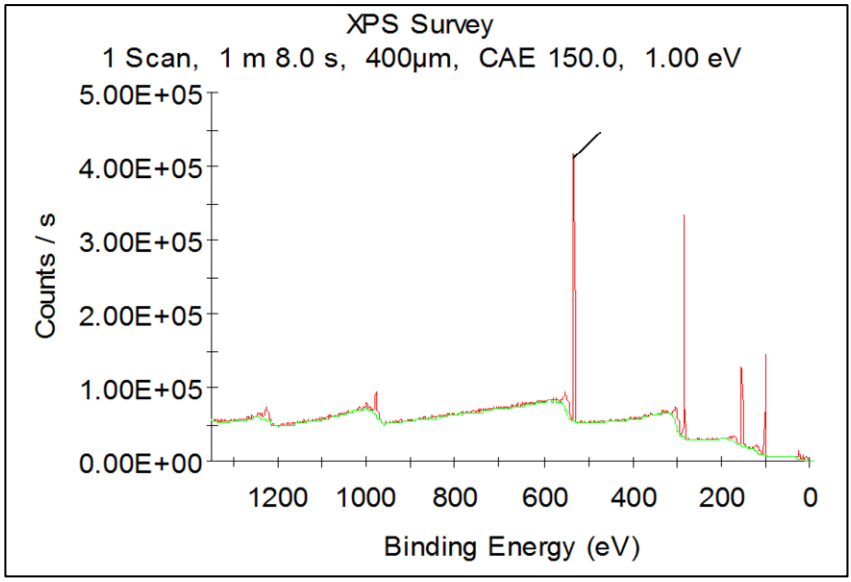

Figure 2. The typical XPS spectrum of Insulator surface.

Table 1. Main element composition and relative content of different samples.

Sample	Si	O	C	Al
RTV	21.49	25.67	51.23	1.61
4	24.44	29.95	44.72	0.89
16	29.7	35.35	34.46	0.49

The water contact angles of the samples were observed by Contact angle meter (SL200B, Shanghai Solon Information Technology Co., Ltd, China). From Figure 3 we can find that the water contact angle of RTV is 118º, the insulator running 4 years is 101º,

and the insulator running 16 years is 90º. With the increase of aging degree, the water contact angle decreases significantly, reducing the anti-pollution flashover capability of insulator surface. This shows that the aging degree increases with the increase of running time.

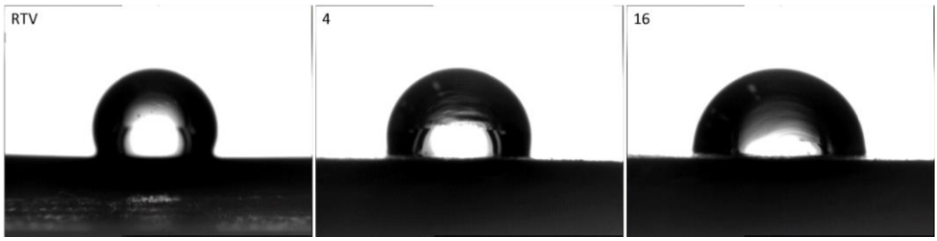

Figure 3. The WCA of RTV and insulators.

FTIR is the study of molecular motion absorption spectra and molecular atoms inside there is a vibration and rotation, when using continuous wavelength ir radiation molecules, and molecular vibration frequency of the same specific wavelength infrared light will be absorbed, resonate, at this point, the molecules in a group is absorbed by the wavelength of infrared energy, Transition to a higher vibrational level; If the frequency of infrared light is different from the frequency of molecular vibration, the infrared light will not be absorbed by the molecular group. This is the basic principle of molecular infrared spectroscopy. Infrared spectroscopy can detect the organic structure and components of compounds in samples, so it is often used to identify and screen the structural changes of compounds.

The FTIR results were obtained by Fourier infrared spectrometer (Nicolet 5700, Thermo Electron, USA). Attenuated total reflection spectroscopy (ATR) technology is used for qualitative analysis, and the oil and dirt on the surface of the test object shall be removed to ensure that the measuring surface is clean and flat. In the IR spectrum, the characteristic peaks of different components are widely dispersed, among which the characteristic groups such as hydroxyl group (OH) are mainly distributed in the high wave-number region, while the groups such as silicon oxygen bond (Si-O-Si) are mainly distributed in 1000-1450cm^{-1}. The decrease of absorption peaks at 1450-1000 cm^{-1} indicates that the content of Si-O-Si in the main chain of silicone rubber, Si-O in the cross-linking group and C-H in Si-CH_3 decrease with the increase of running time.

3. Conclusion

In conclusion, it can be found that the composite insulators in Fujian Province are prone to aging in the operation process, and the aging is aggravated with the increase of the service life. It is mainly reflected in the increase of surface defects, decrease of hydrophobicity, decrease of Al content, increase of oxygen content and decrease of alkyl content, which may be caused by damp heat and ultraviolet aging.

4. References

[1] Xia YF, Song XM, He JZ, et al. Evaluation method of aging for silicone rubber of composite insulator. Transactions of China Electro Technical Society. 2019; 34(s1):440‑448.

[2] Li X, Zhang XM, Shi YH, et al. Aging analysis of vulcanized silicone rubber based on fourier transform infrared spectroscopy. Insulators and Surge Arresters. 2019; (5):216-222.
[3] Wei XX, You CB, Liu WY, et al. Aging and property recovery of liquid silicone rubber composite coat material in converter station. Insulators and Surge Arresters. 2018; (5):145-149.
[4] Tu YP, Wang W, Li M, et al. A study on the influence of ozone on aging of HTV silicone rubber. IEEE Conference on Electrical Insulation and Dielectric Phenomena (CEIDP'09). Virginia Beach, the United States: IEEE, 2009; 92-95.
[5] Tu YP, Tong YL, Wang Q, et al. Influence of humidity on ozone aging performance of HTV silicon rubber. High Voltage Engineering. 2011; 37(4): 841-847.
[6] Li X, Lv QS, Ai JW, et al. Parameter optimization of laser induced breakdown spectroscopy device and principal ingredient analysis of silicone rubber material. Smart Power. 2019; 47(1):72-76.
[7] Qi L, Yan JL, Ouyang XD, et al. Research on ageing test of silicone rubber material for composite insulators. Power System Technology. 2006; 30(12): 91-94.
[8] Sun W, Huang Z, Huang Q, et al. Experimental study on silicone rubber accessories to improve external insulation properties of porcelain post insulators. Insulators and Surge Arresters. 2018; (5):155-160.
[9] Chen C, Lin YF, Jia ZD, et al. Study on the influencing factors of natural degradation of liquid silicone rubber used for external insulation. IEEE Conference on Electrical Insulation and Dielectric Phenomena (CEIDP). Shenzhen, China: IEEE, 2013: 128-131.
[10] Qian WS, Liu Y, Cao Z, et al. Finite element numerical simulation and analysis of the effect of partial micro gap on electric field distribution of composite insulators. Power System and Clean Energy. 2019; 35(6):16-22.
[11] Yang Z, Fan P, Wang QF, et al. Analysis of the electric field through internal gap of composite insulator used in HV transmission lines. Power System and Clean Energy. 2019; 35(6):1-8.
[12] Li HZ. Study on composite insulators fracture fault and preventing methods. Electric Power Engineering Technology. 2018; 37(4):51-56.
[13] Zhang DQ, Liu XW, Liu Y, et al. Hydrophobicity study of composite insulator based on Faster R-CNN. Smart Power. 2019; 47(4):104-109.
[14] Zhang P, Hu PF, Chen XY, et al. Research on hydrophobicity of polymer composite insulator. Smart Power. 2020; 48(12):97-103.
[15] Yang HJ, Wang XN, Wu ZF, et al. Comprehensive summarization of experiences in development, production, operation and test of composite insulators. Power System Technology. 2006; 30(12): 95-97.
[16] Zhang FL, Wang LM. Analysis on internal factors of external insulation material age for composite insulator. Electric Power. 2002; 35(7): 83-86.
[17] Shi R, Huo F, Wan XD, et al. Experimental research on external insulation of composite cross arm for 750 kV transmission line. Smart Power. 2019; 47(10):70-76.
[18] Hillborg H, Gedde UW. Hydrophobicity Changes in Silicone Rubbers. IEEE Transactions on Dielectrics and Electrical Insulation. l999; 6(5):703-717.
[19] Gao HF, Jia ZD, Guan ZC. Aging study on RTV coating covered on insulators and energized for many years. Proceedings of the CSEE. 2005; 25(9):158-163. (in Chinese).
[20] Guo H. New progress of research on ageing of normal temperature vulcanization coating. Electrical Equipment. 2006; 7(1):36-38.
[21] Liang J, Jiao GX, Ma YQ. Study on RTV aging failure treatment. Shaanxi Electric Power. 2011; 39(2):65-67.