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Review on RTV Silicone Rubber Coatings Insulator for Transmission Lines

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Abstract. Nowadays, the usage of RTV Silicone Rubber as Insulator coatings are increased due to its advantages to avoid pollution flashover of contaminated insulator. Besides, the coatings can reduce the maintenance cost and scheduled routine. This paper had introduced the advantage of RTV Silicone Rubber coatings on insulator, such as good adhesion, nominal thickness range and good hydrophobicity. There are three method of coatings application, such as brushing, spraying and dipping. Suitable method is used to specific insulator application. Meanwhile, this paper also explained about installation of coated insulator in the field.

1. Introduction

High voltage insulators are essential for the reliable performance of electric power systems. Insulators are used to separate and support conductors in high voltage transmission system[1]. High voltage insulators are mounted outdoors and exposed to various factors such as electrical, mechanical and environmental stresses.

The electrical stresses are the consequences of regular voltages and over voltages. The mechanical stresses are related to the presence of various loads such as the weight of conductors and hardware. The environmental stresses are consisting of UV radiation, rainfall, dew formation and pollution. According to [2], under the polluted condition, high leakage current will flow on the insulator surface and dry band arching may take place. This may lead to flashover and failure of the transmission lines.

Insulator flashover results in undesirable power outages which are expensive and wasted. Dry conditions of contaminants, which is non-conductive medium does not affect the electrical distribution system. Meanwhile, for wet condition, the contaminants will have ability to conduct electricity [3]. When these pollution deposits become wet, their resistance drops, and leakage current can flow over the surface of insulator.

Under high voltage stress, the current will heat the contaminants area and form dry band region. It will give rise to a leakage current and leads to complete insulator flashover. The washing of insulators is a common method used to remove the accumulations of surface contaminants in polluted areas. This work is laboured intensive, and therefore expensi



2. Room Temperature Vulcanizing (RTV) Silicone Rubber

The application of RTV silicone rubber coating to these insulators eliminates the requirement for frequent washing, thus reducing maintenance costs. RTV coatings are the most widely used as solution to contamination flashovers in high voltage insulators.

RTV coatings have proved as maintenance product with high withstand capability is desired from the viewpoint of seacoast environment and industrial environment due to its effectiveness in preventing contaminations outages [4]. The main advantage of RTV coatings is its hydrophobicity which used to improve the insulator performance in the presence of heavy pollution. Researcher in [5] said that the hydrophobicity of a surface indicates the ability of the surface in repelling water.

2.1 Advantages of RTV Silicon Rubber Coating

Insulation properties of the insulator had improved by coating the surface of insulator with layer of RTV silicone rubber coatings, particularly under wet and polluted conditions. The advantages of RTV silicone rubber coatings are long service life, good dielectric, and flexibility over wide range of temperature can be varied by application of a few dirty environments in service.

As researcher in [6], this environments can make the coatings last for fifteen years and more without maintenance or periodic cleaning schedule. Meanwhile, these coatings also have excellent resistance to ultraviolet radiation, chemical, degradation of thermal and corona discharge. The most significant property of RTV silicone rubber as insulator coating is hydrophobicity and migration of the hydrophobicity. This migration can restore the surface hydrophobicity after the layer of contamination has built up on it [6]. For example in [7], comparison of hydrophobicity effects on coated insulator as shown in figure 1.

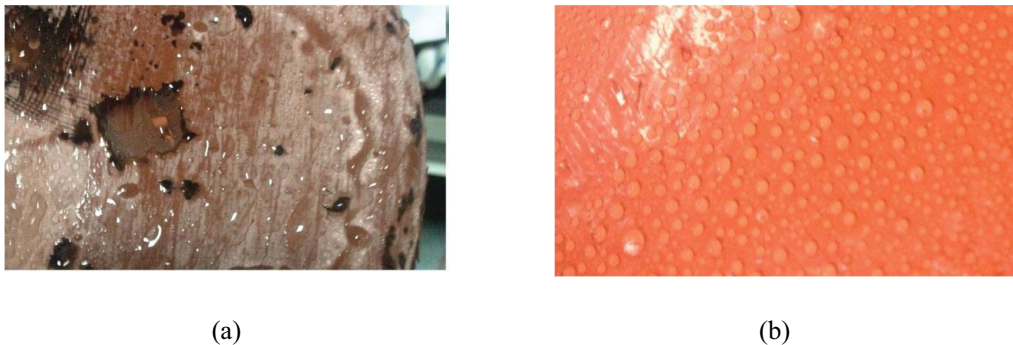


Figure 1. Hydrophobicity on coated insulator. (a) Aged RTV before recoating and (b) coated insulator after recoating [7].

3. Experience of RTV Silicon Rubber Coating Application

Over the past few years, RTV silicone rubber coatings have attracted increasing attention and have been considered for applications on ceramic and glass insulator. Some countries that located in Gulf region may experience severe salt conditions. As shown in figure 2, the failure of 400kV overhead line. Thus, RTV coatings are suitable for Gulf region area.

In 1991, Qatar had introduced earliest RTV coatings application of suspension insulators to transmission lines. The application was installed on a 132 kV lines located in desert sand and coastal salt environment. Normally, insulator located in this environment need schedule water washing for every six months and greased every two years. After 5 years of installation, this lines successfully operate as

flashover-free without maintenance. Later, another 132 kV transmission lines was installed with RTV coated insulator. The lines distance was 85 km from Doha to Dukhan required 55,000 toughened glass suspension insulators.

This newly constructed line was located at extreme service conditions which included frequent sandstorms, salt fog contamination, and carbon pollution from oil operations in Dukhan. Initial purpose for this installation to reduce scheduled water washing, however, the lines had operated nearly 15 years with no flashover and the need for water washing was entirely eliminated. Based on this experience, more coated insulators had been completely installed in 1998, 2006 and 2008 [4].

Meanwhile, in China, the first studies of RTV silicone rubber coating take place at Tsinghua University, 1985 [6]. In 1986, Tianjin Power Supply Bureau had used RTV silicone rubber coatings for the first time to 35 kV transmission line insulator with a small-scaled trial. Next, 1990, the large-scaled applications were installed in Henan Power Supply Bureau and Shandong Power Supply Bureau.

In Hangu of Tianjin Power Supply Bureau, both RTV coated insulators and uncoated insulators were installed with the same pollution and wetting environments. In 1987, there was a heavy fog occur as explained in [4] and [6], active discharge phenomenon acted on uncoated insulator but there was no discharge phenomenon on coated insulator and successfully operated without maintenance until the present day.

Nowadays, most of the substation and transmission in China have been covered with RTV silicone rubber coated in voltage range 10 kV to 500 kV. The first generation of RTV coated insulator have been in service for 15 years and more without flashover and maintenance even there were heavy fog occur in 1987, 1992 and 2001 [6].



Figure 2. Failure a 400kV overhead line in Gulf region [4]

4. Composition of RTV Silicone Rubber Coatings System

RTV is a short form for Room Temperature Vulcanizing which involve the vulcanization process. This is the chemical process that involved the conversion of polymer or rubber into long-lasting material. As stated in [3], RTV Silicone Rubber coatings is a liquid polymer layer that vulcanize inside a flexible rubber layer when exposed to moisture.

RTV coatings consist of a polydimethylsiloxane (PDMS) polymer, a reinforcing filler, PDMS fluid, alumina trihydrate (ATH) filler, colorant pigment, a crosslinking agent, condensation catalyst and an adhesion promoter [8]. ATH is an inorganic filler for tracking and erosion resistance. The solvent namely as naphtha and 1,1,1 trichloroethane are needed as medium to facilitate the transfer of RTV coating to the insulator surface.

Evaporation solvent will form a solid rubber coating when moisture from the air affects the vulcanization. Type of solvent and relative humidity will affect the speed of this process. 1,1,1 trichloroethane solvent act much quicker than naphtha solvent. If the system is drying faster, it will be allowed multiple coats then produced smooth and uniform coats. 1,1,1 trichloroethane solvent is non-flammable compare to naphtha and is suitable for insulator application.

5. Specification of RTV Silicon Rubber Coating on Insulator

The coatings are applied on the surface of porcelain and toughened glass insulator. However, coating on the bottom surface of insulator give no benefit in the cement industry environment. This is because, cement does not bond well with RTV coatings and will lift off from the insulator. Visual appearance of coatings on insulator must be smooth, free of bubbles and lumps. This smooth coating surface help to minimizes the contamination collections and prevent the channelling of leakage current.

5.1 RTV Coatings Adhesion

RTV coatings consist adhesion promoter for bonding to insulator surface. This important element acts as water repellent and help to withstand leakage current development. Otherwise, poor adhesion can cause tearing of coating by the wind and may affect the insulator performance.

Thus, three tests are introduced to the adhesion, such as boiling water test, high pressure wash and scratch test [4]. The boiling water test required the insulator to immersed into boiled water for 100 hours and the insulator coatings is observed. The bubbles and blister will show up if the coating is weak or not bonded to the insulator. The author [4] said, high pressure wash is the power wash using 6.90 MPa with 2 m distance towards the insulator. Good adhesion coating can endure the pressure for 3 minutes, or else the coatings surface will be blown off.

Lastly, the scratch test is performed using a specific tool defined in the standard EN-ISO 2409 [9]. Orthogonal cuts are scratch on the insulator surface as shown in the figure 3 [4]. Good adhere coatings show the orthogonal cuts clearly, while orthogonal cut on poor adhere coatings will lift off the surface.

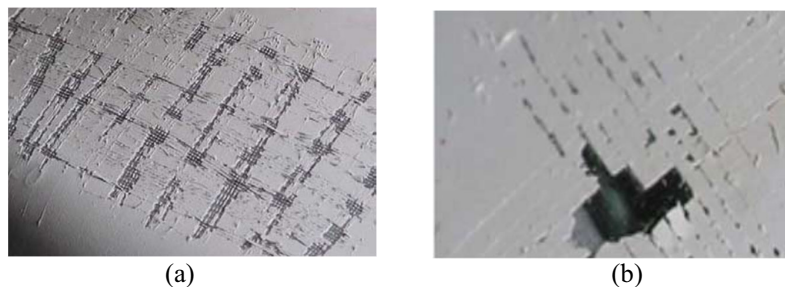


Figure 3. Result of scratch test. (a) On the good adhesion coating and (b) On the poor adhesion coating [4].

5.2 Thickness

Thickness of RTV Silicone Rubber coating can affect the insulator performance. Thickness coatings can imply the damaging magnitude of leakage current around the insulator surface. Thus, previous research in [3] stated the nominal thickness range is specified as 0.3 to 0.5 mm. Thicker coating increased thermal resistance which is slowly conducted the heat away from the insulator. Thus, result in higher hot spot temperature and caused thermal degradation to become more rapidly. Even though thinner coating can allow the heat conducted away quickly, but it will degrade by the environmental forces. Hence, suitable thickness gauge is used to measure the coatings thickness between 0.3 mm and 0.5 mm. Recent research in [10], had introduced Laser-induced breakdown spectroscopy method to measure coatings thickness in short time. However, coatings thickness is not a critical factor compared to other specifications of RTV silicone rubber.

5.3 Hydrophobicity

Hydrophobicity that is the ability of surface to repeal water. This is the most important factors that have been discussed by the previous researcher. Sweden Transmission Research Institute (STRI) had introduced hydrophobicity classification (HC) method which is divided into seven class [11]. The first class is HC1 shows the most hydrophobic surface and HC7 shows the most hydrophilic surface. Hydrophobicity is indicated by contact angle to measure the wettability of surface which the ability of liquids to form boundary surfaces with solid states. The contact angle for hydrophobic surface is between 90° and 180° , while the contact angle for hydrophilic surface is 0° and 90° [12].

RTV coating can provide good hydrophobicity by inhibiting development of continues water films. Due to outdoor service of insulator, the coating hydrophobicity can be lost temporarily but can regain after a certain period. Silicone rubber has the ability of hydrophobicity transfer or migration. The property of hydrophobicity can be migrated to the surface of contamination and RTV coating can recover the hydrophobicity properties. Hence, failure of RTV coating can be verified by identifying the hydrophobicity classification as stated in STRI guide.

6. Method of Application

Cleaned insulator is compulsory before coated procedure has been applied. This is to avoid contaminant from wrecking the form of RTV layer and may lead to bad insulation performance. Effective cleaning method to remove common contaminant is washing with high pressure water. However, this method is not suitable for insulator that have coated with grease or silicone rubber because the coating is difficult to peel off. If the coated insulator had been on service for long time, the ability as anti-pollution flashover will be decreased.

As stated in [13], insulator shows several problem, such as coating cracking, peeling and poor adhesive force after 12 years in operation. Thus, new coating is needed to maintain good performance of insulator service in transmission line. To clean the old coating of insulator, manual scraping method is used [14]. Scraper is used to remove the old coating and then hand wiping the residual. Researcher in [10], has studied the feasibility of cleaning RTV coatings with fiber lasers. This paper test two kinds of fiber laser, which is pulsed laser and continuous laser.

There are three method for coating application to insulator, such as brushing, dipping and spraying. Brushing is the most economical method but difficult to apply uniformly and quickly. Suspension insulator used dipping method to apply the coating. Spraying method is the best method because it can form smooth silicone surface. For brushing and dipping method, one layer is enough to obtain complete coverage while, for spraying method required two or three layer which depends on the equipment that has been used. Each layer can be applied after the surface of previous layer is tacky.

Packaging of new coated insulator is needed to protect the coating from injury during transport. The insulator can be wrapping using bubble packaging or else crating using Styrofoam lined. The crates need to be stacked vertically on pallets during shipment to reduce the damage on the coating layer.

7. Installation Coated Insulator in the Field

In [15], coated insulator has low tear strength and need to be handled with care to minimize damage on RTV coatings. Strings insulator cannot be assembled in the ground which is the usual way to installed uncoated insulator. To minimize the damage on insulator during installation, the insulator is remained in crates until ready to be raised into position. However, the insulator needs to be replaced or repaired with spray kit, if there is major scrape especially along the creepage path. Based on previous experience, there is no maintenance needed after RTV coated insulators were installed in lines. Nevertheless, monitoring only be done when there is high severity of pollution occurred. Insulator condition can monitor by audible detection of partial discharge. When the contaminant accumulates surround the insulator, audible noise of corona discharge and dry band arcing will increase. Thus, corona ultrasound sensor is used to locate the source of noise. Besides, the polluted insulator can be monitor using visual detection. Binoculars is used to view at close range the evidence of dry band arcing and possibly lead to poor coating adhesion. Otherwise, corona camera is used to view the insulator during wet condition. If the condition of polluted insulators is worst, water washing is needed to prolong the coated insulator's life and reduce the dry band arcing damage.

8. Conclusions

In this paper, understanding of RTV Silicone Rubber coatings is increased for transmission line insulators. Usage of RTV Silicone rubber as insulator coatings are worldwide that can increase efficiency of insulator in transmission and reduce maintenance cost. Main advantage of RTV coatings is good hydrophobicity. This advantage help to reduce the formation of contaminant surround the insulator and increased the lifetime of insulator. Besides, suitable composition of RTV silicone rubber coating is needed to produce good coatings. This paper had highlighted, the specification of RTV coating for insulator, such as coating adhesion, thickness and hydrophobicity. Lastly, method of application and installation are crucial in development of RTV coating insulator to increase the insulator effectiveness.

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