Silicone Coating on Porcelain Insulator

Melchor S. de Roma, **Amjad A. Al-Blewi, Maryam K. Al Jarman, Abdul Waqas Abro**

Abstract: ***Dubai Electricity and Water Authority (DEWA)used porcelain insulators in the transmission overhead line system. These insulators are considered the best insulators with regard to design and durability. In spite of satisfactory performance, porcelain insulators have disadvantages, such as needing regular washing and cleaning. Because of the coastal location and industrial pollution of the overhead lines, frequent washing of porcelain insulators is required to ensure an interruption-free and reliable performance. Various studies have been conducted on the operation of porcelain insulators, i.e. flashover from heavy pollution during foggy and stormy weather, extremely high and long periods of high humidity, industrial and dust contaminants. These studies suggested the right specification for creepage distance of insulator strings in different environments. Nevertheless, they have not provided sufficient protection against pollution deposits. This has introduced the development and application of high-voltage silicone coating to porcelain insulators provides adequate protection from pollution. This has provided high-quality performance, durability, and long life, without requiring regular washing, making them superior to glass and composite insulators. This report guides engineers and other utilities, particularly countries with environmental conditions like Dubai, in selecting the precise insulator to be used in their overhead line system. It also provides a way to improve the existing insulator they have on their system.***

Keywords: Silicone coating on porcelain insulators

1. Introduction

DEWA began the construction of the 400kV Overhead Lines in 1990.The main component of the overhead transmission lines was composed of 400kV single circuit towers, three-phase bundle of four conductor and porcelain insulator strings. An insulator is the cheapest and smallest part in the overhead line. Yet its functionality is the most important integral equipment in the electrical power system as it plays a vital role in protecting transmission lines, power transformers, circuit breakers, and other significant apparatus in the electrical network.

To keep the line healthy and maintain sustainability and reliability of the system, checking and protecting of all insulators are being conducted regularly in all transmission lines. A line insulator should always be clean to ensure that it will withstand over voltages such as switching and lightning surges. Ideally, if an insulator fails, it should only be limited to flashover rather than a puncture.

Dubai is located in an arid region with a coastal environment, with infrequent and short periods of rainfall. Further, the coastal environment creates salt pollution. This pollution increases the Equivalent Salt Deposit Density values on insulators. Other areas with dusty and sandy pollution have increased Non-Soluble Deposit Density values of the pollution layer.

The effects of Contamination in insulators can be visualised by condition-monitoring techniques such as UV scanning (Fig.1). If such contamination is prevalent, it may cause flashovers and ultimately damage insulators. Factors that contribute to flashovers are the following:

- Climate, which is composed of wind, rain and condensation fog
- Pollution and composition
- Insulator shape, and leakage distance
- Insulator position, which includes the height of insulators above ground level, the orientation of insulator strings and distance between insulators and source of pollution.

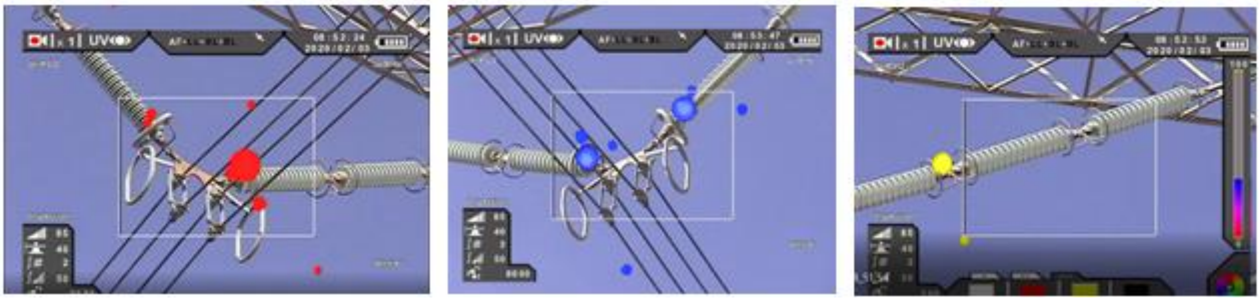

Figure 1: Contaminated Porcelain Insulator Discharge based on UV Imaging

1. CIGRE Studies, IEC and IEEE standard

For a contaminated environment such as Dubai, it is important to know and understand the specific requirement of the creepage distance of insulator. The Conseil International des Grands Reseaux Electriques (CIGRE) or Council for Large Electric Systems conducted the analytical expression between creepage distance and salt density for polluted insulator, which was derived using Dimensional Analysis Technique. The site severity and ESDD studies conducted by CIGRE compare with IEEE with the specific distance requirement shown in the below Table 1.

Table 1: Contamination site severity, IEEE (1313.2-1999) and Creepage distance (2000 conference on Electrical Insulation, Canada)

Site severity	ESDD, mg/cm^2		Specific Creepage Distance (mm/kV_{L-L})	
	CIGRE	IEEE	CIGRE	IEEE
None	0.0075 – 0.015			
Very light	0.015 – 0.03	0 – 0.03	20	
Light	0.03 – 0.06	0.03 – 0.06	25-30	
Average/Moderate	0.06 – 0.12	0.06 – 0.10	30-35	
Heavy	0.12 – 0.24	> 0.10	40-45	
Very heavy	0.24 – 0.48			50-5
Exceptional	> 0.48			>55

Where Equivalent Salt Deposit Density (ESDD) means the amount of sodium chloride dissolved in water. This will change the conductivity of water to the level equal to the ratio of resulting pollution deposits on insulator and its surface area. While Creepage distance is the shortest distance, or the sum of the shortest distances, along the insulating parts of the insulator between those parts which normally have the operating voltage between them.

According to CIGRE, the insulation strength of the contaminated insulators caused by spraying seawater and industrial fumes is dependent on many variables:

- The type and amount of contaminant and inert binder
- The configuration of the insulator
- The length of the insulator string
- Weather conditions and testing method

Typical environment compares with its pollution level; Specific Creepage Distance and the basic Unified Creepage Distance (USCD) categorized by IEC 60815-2/60071-2 mentioned in Table 2.

Table 2: IEC 60071-2 recommended creepage distances and RUSCD (IEC 60815-2)

Pollution Level	Examples of Typical Environments	Specific Creepage Distance for 3 phase AC systems	Basic USCD (mm/kV)
Very Light		12.7	22.0
I Light	In areas without industries and with low density of houses equipped with heating plants, Agriculture and mountainous areas, situated at least 10-20km from the sea and not be exposed to winds directly from the sea.	16	27.8
II Medium	Areas exposed to wind from the sea but not close to the coast. High-density residential areas are subject to frequent winds and rainfall.	20	34.7
III Heavy	Areas with a high density of industries and on the outskirts of large cities with a high density of heating plants that produce pollution. Areas close to the sea or in any case exposed to relatively strong winds from the sea.	25	43.3
IV Very Heavy	Areas generally of moderate extent subjected to conductive dusts and to industrial smoke producing particularly thick conductive deposits. Desert areas, characterized by no rain for long periods, exposed to strong winds carrying sand and salt, and subjected to regular condensation.	31	53.7

Where Specific Creepage Distance isthe distance where the line-to-line value of the highest voltage is used (for A.C. Systems usually $Um/\sqrt{3}$.)

Unified Specific Creepage Distance (USCD) is the creepage distance of an insulator divided by the R.M.S. value of the highest operating voltage across the insulator.

Table 3 shows the comparison of contamination by CIGRE and IEEE. The specific leakage distance of ESDD measured on I-strings using different type of methods.

Table 3: Comparison of contamination minimum requirement, IEEE vs CIGRE specific leakage distance for I-strings (1313.2-1999)

Method	CIGRE			IEEE
	England	Germany	Japan	USA/Canada
ESDD (mg/cm^2)	Unified Specific Creepage Distance, USCD (mm/kV- line to ground)			
	Salt Fog	Kieselguhr	Fog Withstand	Clean Fog
0.03	32	22	30	23
0.06	38	29	36	30
0.10	42	35	41	34
0.40	58	60	57	41

For Salt Fog (English) method:
$L_C = 2.34\ Sa^{0.224} = 7.09\ ESDD^{0.224}$

For Kieselguhr (German) method:
$L_C = 1.42\ \sigma_w^{0.387} = 8.15\ ESDD^{0.387}$

L_C = is the recommended Leakage distance
S_a = is the amount of salt in the water, used for the test in kg/m3
σ_w = is the insulator surface conductivity in µS

In the design of the insulator for desert regions, the first thing to consider is the contamination level in the area where the transmission line is to be constructed. Since data for contamination level are not accurately available, the experiences in various desert areas were taken into account, and at least an average of 40mm/kV creepage distance is necessary for the transmission line near the coast of desert areas. However, in desert regions like Dubai, which is heavily contaminated, a Specific Creepage distance of 55mm/kV is advisable.

2. Solutions

The cost incurred to carry out maintenance of the porcelain insulators is very high. This is attributed to the manpower utilized, conditioned monitoring such as during night time corona-monitoring and Reliability Centred Maintenance(RCM) activities like washing of insulators using high consumption de-mineralized water and equipment machinery.

Hence, to avoid leakage current flashovers on porcelain insulators due to contamination accumulation of the insulator surface because of the continuously exposed to the harsh desert environment, DEWA implemented the application of silicone coating on the insulator's surface as this application was applied on the Terminal Ends of OHL.

A single Component Room Temperature Vulcanizing (RTV) silicone coating on Porcelain insulators is obtained to provide long-term highly hydrophobic surface; as a result, it will limit the leakage current, decrease the pollution and prevent flashovers due to insulator contamination. Further, the silicone coating is not affected by UV light, corona discharge, chemical contaminants, salt and extreme temperatures or corrosive environments.

The benefits of RTV coated Porcelain insulators are twofold – Sturdiness of Porcelain insulators and pollution performance of Silicone insulators. It also reduces the O&M cost of frequent cleaning and washing of insulators.

The application of silicone coating on the 132kV and 400kV terminal ends have been found successful, as it was able to avoid 799 outages and 1300 number of live line washing per year, resulting to savings of about 230, 000 Imperial gallons of water annually.

Manual Cleaning   Live Line Washing   Silicone Coating

Figure 2: Cleaning, washing and silicone coating on porcelain insulator

3. Difficulty

Although it may seem that application of silicone coating is an easy task, there are some challenges and difficulties on the application of silicone coating:

3.1. Ensuring Even Coating Thickness

Difficulty in ensuring even-coating thickness on the surface of the insulators due to the height of the tower. Even application cannot be done if the airless spray gun will be lifted on top of the tower by using a bucket lift truck. It will also be difficult to install scaffoldings to be positioned near the tower to carry off the silicone spraying.

Based on the normal practice, the typical silicone coating thickness applies on the porcelain insulators is from 0.3 to 0.6 mm (300 to 600 micron). However, the perfect thickness still depends on the formulation of the materials used in the polymer substance.

3.2. Spray particles to affect nearby houses or vehicles

One of the complications that we experienced during the silicone coating is that the spray can affect the surface of nearby vehicles or structure. If not controlled, this will lead to instigating complaints from car and building owners.

3.3. Complications to spray the insulators from ground

To ensure even-coating thickness, a process it is preferable to bring down the insulators and spray it on the ground. However, it is difficult as dismantling, spraying and installing insulators take long processes and cannot be adopted due to limitation on the allowable outage period.

4. Results

Based on the best practices in technology, we can affirm that the best and preferred solution to improve the insulation of porcelain insulator is by Application of RTV (Room Temperature Vulcanized) Silicone Coating on the Porcelain Insulators. Significant advantages are as follows:

- Require short outage duration
- Long-term hydrophobicity feature (capable of repelling moisture) prevents the accumulation of contaminants and salt content on the surface of the insulators.
- Long life cycle of about 15 to 20 years.
- No routine manual cleaning is needed for the life cycle of the silicone coating
- Reduced maintenance expenditure, as in washing, compared to conventional insulator surfaces.
- Nontoxic and environmentally friendly material.

5. Conclusion

The following conclusions can be drawn based on the experience of application of silicone coating on porcelain insulators;

For the pollution performance, the short-term and long-term hydrophobicity characteristics of silicone coated porcelain insulators are better than the uncoated porcelain insulators at the same site. The number of high pulses of the leakage current provoking flashover is lower for silicone-coated insulators.

For the ageing, an application of silicone coating improved the existing high durability of porcelain insulators.

Considering above facts, and the results of the study, economic analysis and calculation, silicone coating is an effective, economical and reliable application on porcelain insulators, which can be aptly used in dry-weather areas such as Dubai and other countries with similar climate conditions.

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