

TECHNICAL & ECONOMICAL EVALUATION OF USING SILICONE RUBBER RTV COATING FOR H.V. SUBSTATION IN POLLUTED AREA

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Abstract:

High voltage insulators have to be used as insulating supporters in various environments in polluted area. The electrical performance of insulators will be degraded. The polluted insulators will have over withstand voltage, flashover can occur easily when the air becomes wet by humidity or fog, which affects on the reliability of the power systems.

In order to define effective counter measures against pollution flashovers there are conventional methods such as periodically water washing and also using silicone grease for insulation. Water washing of insulators which is normally recommended so as to remove the pollution from the insulator surface needs to be done more frequently than other maintenance methods. Though involves some limitation in practice from the technical and economical point of view. Applying of silicon grease on insulators with high cost of performance also is not recommended for use in an environment where high level of NSDD pollution is present. In this paper room temperature vulcanizing (RTV) silicone rubber coating have been presented as a novel approach for improvement of outdoor substation insulators maintenance in polluted area. This method can be used in areas characterized with "Instantaneous pollution" and or with "High or Low level of NSDD" with long life expectancy. Financial analysis shows that this method is also economic and optimal choice.

1-Introduction

HV insulation separates voltage levels. Wet polluted deposition forms conductive layer. This layer extends gradually and causes electrical breakage as well as outage. Therefore, appropriate insulation design plays important roll in system reliability improvement and faults reduction in polluted regions. According to utility records, inappropriate insulation constitutes 70 percents of HV lines faults. Respecting to international standards, coastal regions of Persian Gulf and Oman Sea are classified in "very heavy" pollution degree and their hot and humid climate, sea adjacency and salty water provide specific condition. Present insulation design of HV device-lines design in the regions is based on "very heavy" pollution degree standards, but the insulation performance is inefficient. Insulation weaken is the main effect of pollution. Different methods, e.g. periodical washing, are used to reduce these effects in southern regions of Iran.

In this paper, traditional maintenance methods in HV substation as well as RTV silicon rubber coating, as a replacement, with their technical-economical considerations are presented and calculations for a typical substation performed.

2-Typical maintenance methods in polluted regions

Different maintenance methods based on sweeping pollution or changing surface characteristics are applied in polluted zones. They are commonly as follows:

- Periodical washing
- silicon grease

2-1-Periodical washing

In this method the HV insulators are washed periodically with distilled water. Times and intervals of washing are determined according to site pollution degree, atmospheric conditions and insulators shape. Insulators should be washed before critical pollution achievement. This critical value is estimated based on ESDD value of pollution gauges (if valid), environmental conditions and operation experience. Washing is applied manually or with spray (hot or cold). Finally, insulators should be dried to avoid leakage. Manual washing is one of the most effective pollution sweeping methods, but it is time consuming and difficult. Also, it is useless for instant pollution. Instant pollution is a high conductivity pollution that deposit quickly on insulation, change the clean surface to spark situation less than one hour and return to base state after electrical breakage. This type of pollution is found in coastal region with salty water or conductive fog deposition and sea salty water, SO₂ (produced by factories) and road salt scattering are the resources.

Furthermore, in these methods, intervals are shorter than the others and the appropriate time determination are difficult. If substation deenergize is unfeasible, spray can be used. This method is faster and easier than manual one, but its electricity consumption necessitate special devices as well as lower conductivity distilled water. Electrical breakage threatens during application. This method is used in southern regions of Iran and times and costs are very high for "very high" pollution degree in these regions.

According to IEEE 957, washing material in this method is distilled water. The required cost for hot washing is presented here. Low conductivity distilled water with 2725 to 6900 kPa pressure scatter on insulator surface. The other requirements are available in [5]. The main costs are as follows:

- Distilled water preparation
- Operational personnel
- Washing devices wear and tear
- Water and devices transportation
- Peripherals cost

Washing is periodic and more than one time a year. The intervals are determined by pollution degree.

2-2-Silicon grease

Silicon grease coating is used more than 25 years as protective layer in porcelain and glass insulators. All kinds of available grease have water repellency and low surface energy. The grease layer converts the insulator surface to water repeller (figure 1). The deposit pollution surrounds by the grease and avoids conductive layer formation. The grease surface should be inspected for erosion; oxidation or tracking. Grease oxidation is shown in figure 2. Grease can be applied manually or by spray. If it is applied correctly, lasts for one year. In spite of usefulness in instant pollution (at the contrary of washing), it is useless in high NSDD regions. Also, intense wind and rain remove grease layer.

High application cost, time consumption and difficulty are the main restrictions. However, second greasing necessitates removing previous film.

Greasing is applied manually or by spray, but spraying is preferable and performs in cold state. The followings should be considered:

- Technical conformation
- Minimum thickness (determined by pollution degree)
- Dimensions and clearance distances
- Previous layer careful removal

The main costs are as follows:

- Surface preparation
- Grease preparation
- Substation deenergizing
- Application cost

Insulators surface should be determined for cost estimation and application is according to standards. Calculation process is presented in appendix B.

2-3-RTV silicon rubber coating

These coatings are applied increasingly for porcelain and glass insulators or bushings. This method is an efficient replacement for the above. The operation mechanism is the same as greasing except NSDD affectivity.

There are RTV coatings with different performances. The key point in their performance is their ingredient. The coatings that lost their water repellency by environmental factors have short life and inefficient performance in breakage elimination.

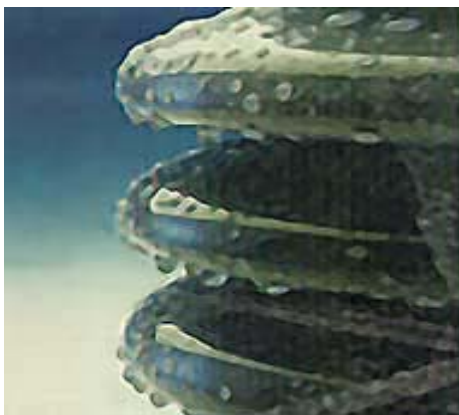


Figure1: insulator surface hydrophobicity after greasing

Convenient application is another advantage that affect significantly on cost. Insulator surface should be cleaned before coating. It is recommended to wash surface by high pressure water and sweep with isopropyl alcohol. If grease previous coating available, it should be solved with proper solvent (e.g. Nafta).

Having surface prepared, coating should be provided. Film characteristics (i.e. maximum thickness that deposit by one time spraying) play the main roll in operation time and cost. The layer thickness is influenced by viscosity, deposit characteristic and surface material. Drying time consumption is determined by solvent. 1, 1, 1-terichloroethan is the most common solvent. This solvent reduces dry time by 30% compare to Nafta. Lower time, lower the cost. The other effective parameters are studied in next part.

RTV silicon rubber coatings provide water repellency for insulators. Coating life depends to site pollution degree, insulator dimension and coating application. According to IEC 60815, additives can increase life and creepage distance. More ten years life is achieved in this method.

RTV is the only way to defeat high pollution degrees for irreplaceable insulators and provide long life and applied hot or cold.

As well as greasing, the surface should be cleaned. Application cost in hot state is calculated and classified as follows:

- Insulator preparation
- Material cost
- Application cost

Material cost estimation requires thickness as well as surface area. The desirable thickness is between 0.3 to 0.5 mm. At the contrary of greasing, the thickness is independent of environment pollution degree.

3-Technical-economical assessment of different maintenance methods in Qeshm substation [4, 8, 13]

Technical and economic assessment of different maintenance methods is applied on a 230kV substation in Qeshm. This substation contain 20, 63,230 kV voltage levels in addition to a 230kV and six 63kV feeders. The single line diagram is presented in appendix A.



Figure2: Grease oxidation

NSDD and ESDD index of this substation is very high. The measured indexes are shown in table 1.

According to the results and IEC 60815, this region is classified as “very heavy”. This level is approved by operational records. In this section, a comparison of different methods presented.

Table 1: Queshm pollution measurements

Station	ESDD(mg/ cm ²)	NSDD(mg/ cm ²)
Gheshm, HR-72-12	1.338	6.8716

3-1-Periodical washing

Nowadays, washing is applied as maintenance method in this region. Annual periods are proportional with pollution degree. According to pollution index and Hormozgan utility reports, this substation is washed 20 times a year. Each time cost is presented in table 2. Therefore the annual cost is 162000000 Rials.

Table 2: one time washing cost in a typical substation

	Cost (Rial)
Distilled water preparation	2,600,000
Operational personnel	1,000,000
Water and devices transportation	4,000,000
Personnel transportation	300,000
Peripherals cost	200,000
Total	8,100,000

3-2-Silicon grease

Silicon grease covers insulators surfaces. This method is inefficient in high NSDD regions. Therefore, in Queshm, washing is not an appropriate alternative. Nevertheless, the calculation performed. As mentioned in previous sections, having cleaned the surfaces, the grease applied. The procedure increases application time and cost.

Grease preparation is another cost effective part. Film thickness and total surfaces should be calculated. In this method, total surfaces of insulators are covered. H.V devices list are available. Side surfaces of insulators are calculated according to appendix B. It should be note that the suspension insulators in the substation are silicon type and greasing is not required. There are different types of greasing, so the applied covering should be chosen respect to regional condition.

The required thickness and grease is based on [4]. According to site pollution severity, chosen grease and table 3 the required thickness is 3 mm. Third parts is application. This part consists of operational personnel cost as well as devices. This method is applied deenergizedly. So, substation deenergization, device wearing, undistributed energy, decrement of reliability and network security is cost effective. Total cost is presented in table 4.

If the covering applied correctly, it remains for a year. After a previous film). Therefore the recovering cost is 15730000 Rials.

Table 3: grease weigh and thickness proportional with pollution degree

Pollution Level	Grease Thickness (mm)	Grease weight (kg/ m ²)
Medium	1.5	3.0
Heavy	2.25	4.0
Very Heavy	3.0	5.0

Table4: typical substation greasing cost

	Cost (Rial)
Insulator surface preparation	12,100,000
Grease cost	275,000,000
Devices and personnel transportation	10,000,000
Application cost	25,000,000
Peripherals cost	500,000
Total	322,600,000

3-3-RTV

RTV coating is applied respect to IEEE 1523. The economic calculation and initial cost is based on standard and [4], respectively. The covered devices are the same as 2-2. Note that, suspension insulators, surge arresters, 20 kV CTs and PTs are silicon type and coating is unnecessary. Coated surfaces are calculated according to 2-3 and appendix B. Having calculated the surfaces, the thickness is determined respect to [4,6]. The required material for 1 mm² insulator surface is presented in table 5. According to these data and total surface, the initial material is calculated. Total cost presented in 6. If the covering applied correctly, it remains for ten years. After ten years, the previous firm should remove completely for recoating.

A thirty years maintenance period is considered for comparison purpose (table 7). According to the table, 1-3 is plotted. It can be seen silicon grease cost is twice the periodical washing .RTV is very economical respect to its ten year life.

Table 5: RTV weigh and thickness

Pollution Level	Thickness (mm)	Weight (kg/ m ²)
Medium, Heavy and Very Heavy	0.38	0.77

Table 6: RTV coating cost in atypical substation

	Cost (Rial)
Insulator surface preparation	12,500,000
Material cost	474,000,000
Devices and personnel transportation	9,000,000
Application cost	30,000,000
Peripherals cost	800,000
Total	526,300,000

Table 7: comparison between maintenance methods cost

Years	Water Washing Million Rials	Grease Coating Million Rials	RTV Coating Million Rials
1	160.2	322.6	526.3
5	810	1613	526.3
10	1620	3226	1052.6
15	2430	4939	1052.6
20	3240	6452	1578.9
25	4050	8065	1578.9
30	4698	9355	1578.9

4-Conclusion

In this paper, RTV covering presented as an effective and economic maintenance method. In addition, this method compares with alternatives and economic calculation is presented for 230kV substation in Queshm.

In present day, maintenance method of the substation is 20 times annual washing (respect to pollution degree). Washing is limited by technical constraints and is not economic. Also, it is not effective in instant pollution and high NSDD regions (e.g. Queshm and Jask).

The RTV method has not above limitations and the initial cost obtained in the first 40 month.

Therefore, HVIC is the only appropriate method for high NSDD and “very heavy” pollution degree regions and recommended.

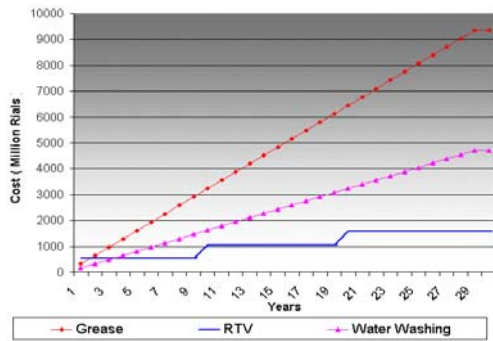


Figure7: comparison between maintenance methods cost

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Appendix A

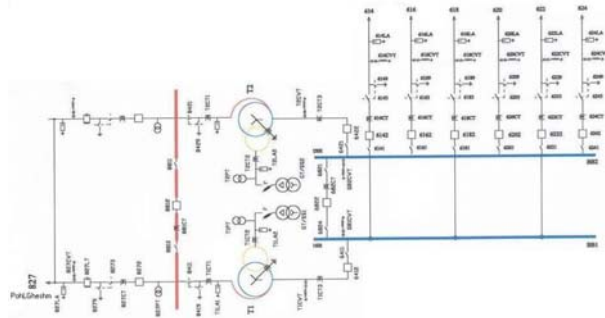


Figure A-1: Single line diagram of Queshm 230kV substation

Appendix B

Type and characteristics of HV substation should be known for surface calculation. According to figure c-1 and substation data, device are listed in table 4-3. Depend to the insulator type, external diameter and creep age distance is required for the calculation. Side surface is achieved approximately by eq A-1.

$$A_s = \pi \cdot d_j \cdot \frac{(D_c + D_s + D_l)}{3} \tag{A-1}$$

- A_s: Insulator side surface (m²)
- d_j: Creepage Distance (m)
- D_s: Diameter of smallest shed (m)
- D_c: Diameter of core (m)
- D_l: Diameter of largest shed (m)

For example, side surface of a 63 kV current transformer achieved 1.80 m² by eq. A-1. Necessary data is shown in A-2. Now, considering surface, table 3 and 5, the required material grease is obtained.

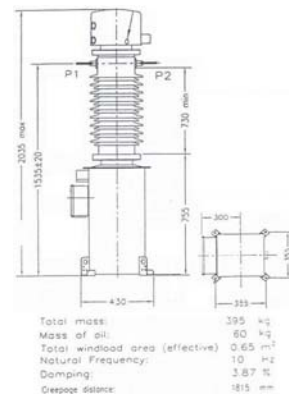


Figure A-2: 63kV Current transformer