ECONOMIC EVALUATION OF USING HIGH VOLTAGE INSULATOR COATINGS (HVIC) FOR ELECTRICAL SYSTEM

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***Abstract*— High voltage insulators serve as a boundary for free-flowing electrons from an electrically charged part of an equipment to a charged and uncharged material. However, performance of an insulator degrades as time passes. Insulator surface under excessive condition such as pollution and changing weather, contributes to a quicker material breakdown. Several methods especially on high voltage systems were introduced to mitigate rapid material degradation – traditional periodic washing, silicone greasing and room-temperature vulcanizing silicone coating or RTV coating.**

I. INTRODUCTION

According to records from an Iranian Utility, 70% of high voltage line faults are caused by inappropriate insulation [1]. Also, a technical researcher from Virginia pointed out that as often we think of generators as a suspect to power failures, insulation failure would often be the cause and records are increasing [2]. Therefore, proper design, installation and maintenance of electrical insulator at different voltage levels plays a very important part on the system reliability. Thus, as one of the key factors, different maintenance methods were adapted to preserve the effectivity and functionality of electrical insulators. Economic evaluation of conventional methods such as periodic washing and applying silicone grease as well as high voltage insulator coating or RTV silicone coating are presented in this study. This is to evaluate which among these methods aside from its effectiveness but also associates a higher maintenance cost and material.

Data were sourced out from different studies, documents and technical evaluation conducted by different organizations to come up with a cost comparison between traditional washing, silicone greasing and RTV coating. Study variables and scenarios were introduced to put the comparison into detail. Note to readers that different sources reflect a different time, different electrical system capacity and location, and a different economic value, thus a difference in cost may greatly contribute on the beforementioned parameters.

II. MAINTENANCE METHODS

A. Traditional Periodic Washing

This method used distilled water to wash high voltage insulators periodically. This method proved as effective as any method however it is usually discouraged by many for its time and material consumption. Time and interval of washing depends on the degree of contamination, actual site weather condition, and design of insulators. Water washing from ground zero provides insufficient pressure to drive the cleaning at a typical high voltage tower height. Linemen needed to climb towers and wash using sprays under energized condition. This is easier but the safety considerations are exorbitant and adding up cost for special equipment and a high resistivity or low conductivity water (as per IEEE 957) [5]. Periodic washing could also be done under de-energized condition to exempt the clearance requirements of washing. However, cost of shutdown should be considered for the total maintenance cost. Washing period is typically more than one time annually. [1][3] Major cost considerations for periodic washing are the following:

- Preparation of high resistivity water
- Labor costs
- Washing equipment (depends on the washing method)
- Equipment and water transportation
- Peripheral costs
- Power shutdown costs (if applicable)

B. Silicone Grease

Since the 1960’s, utilities have used "silicone grease" with good results to prevent the effects of pollution on the insulators surface. Its water repellent and arc track resistant surface, it encapsulates pollutants, has a good performance and lower lifetime costs than water washing. Greasing can be applied in two ways: manually or by spraying. [1][3] The following parameters should be considered for silicone grease application cost:

- Silicone grease preparation
- Insulator surface preparation (including removal of previously applied grease)
- Equipment costs
- Equipment and silicone grease transportation
- Labor costs
- Peripheral costs
- Power shutdown costs

Silicone grease application depends on the severity of site pollution, from medium level to very heavy. An increase on the severity of pollution level will also increase the grease thickness and weight requirement as well as the overall maintenance costs. Compared to traditional washing, a correctly applied silicone grease would last for a year. Thus, silicone grease application is required only one time annually.

C. RTV Coating

RTV coating or high voltage insulator coating (HVIC), has been developed and applied rapidly as it suppresses the development of leakage currents due to a dynamic and interactive surface which retards water film formation and contamination solubility. Its hydrophobic surface prevents water filming, then the surface oil coats the contaminant particles and renders them hydrophobic. This reduces the contaminants' ability to combine with water to form an ionic solution. The RTV coating maintains these features over the long life of the installation. They are the most competitive solution over long term, by providing arc track resistance additives, unparalleled UV resistance, Superior adhesion, wide temperature stability and hydrophobicity. Its long-term effectiveness affects significantly on lowering the total maintenance cost. Same with silicone greasing, insulator surface should be prepared before coating. Spraying is the most efficient method of RTV application. Another advantage to the overall cost is the ability to apply RTV coating under de-energized condition. Thus, power shutdown costs can be excluded on the computation for annual maintenance cost. [1][3] The following items are to be considered in RTV application cost:

- Insulator surface preparation (including removal of previously applied grease)
- HVIC costs
- Equipment costs
- Labor costs
- Peripheral costs

III. ECONOMIC EVALUATION

Different studies were conducted as to compare the equivalent costs per method introduced for insulator preservation. As to this document, we will be focusing on the comparison between traditional washing and RTV application only, since the cost for silicone greasing lies between the other two as mentioned on the above sections. Breakdown of the total maintenance costs were considered – Material and installation cost, power outage cost and annual leakage cost.

A. Material and installation cost

[3] For traditional washing, data supplied from a contractor based in Middle East assumed the total material and installation cost, under energized condition, would amount to 600,000 USD.

[3] On the other hand, material and installation cost for HVIC application based on average product cost and local labor rates would amount to 3,900,000 USD.

B. Power outage cost

[3] Traditional washing assumed to have an average of ten (10) outages per year after Year 4. For a 500 MW system at a rate of 0.018 USD per kWh, total outage costs would sum up to 2,160,000 USD.

[3] For HVIC application, Total amount of outage cost assumed for a total of ten (10) outages per year is negligible.

C. Annual leakage cost

Annual leakage cost is the total amount loss due to leakage current for uncoated insulators. This cost exempts the RTV application considering the minimal amount of leakage current occurrence after coating, averaging a less than 10 microamperes of leakage current. [3] For traditional washing method, uncoated insulator produced the following average leakage current depending on the site condition:

- 973 hours of fog causing an average of 10 mA of leakage current
- 0 hours of rain causing an average of 20 mA of leakage current
- 7,787 hours of dry season causing an average of 1 mA of leakage current

An average of 2 mA leakage current per string can be obtained for an uncoated insulator. A method of obtaining the total cost of leakage current involves the following parameters:

- Average leakage current per string
- Number of strings
- Voltage level
- Per kWh cost

[3] Considering as an example is a 400-kV, 200-km double circuit line, will have a total of approximately 2240 strings. Using the above average leakage per string of 2 mA at a rate of 0.018 USD per kWh, the total annual leakage current costs would sum up to 193,870 USD.

IV. COST COMPARISON

Note that the above computation does not represent to all existing transmission line design. Thus, an increase in length and number of strings based on the stringing configuration would significantly increase the total annual leakage current costs.

Comparison table for the equivalent annual costs of traditional washing and HVIC application are shown below.

TABLE I. COST COMPARISON FOR TRADITIONAL WASHING AND HVIC APPLICATION

Methods	**Cost breakdown**		
	Material and installation cost	***Power outage cost***	***Annual leakage cost***
Traditional washing	$ 600,000	$ 2,160,000	$ 193,870
HVIC application	$ 3,900,000	$ 0	$ 0

For ten (10) years, the total annual costs for both methods are presented below. Note that power outage cost for traditional washing starts after Year 4.

Year	Traditional Washing			HVIC Application		
	Material and Installation Cost	Power Outage Cost	Annual Leakage Cost	Material and Installation Cost	Power Outage Cost	Annual Leakage Cost
1	$600,000	$0	$193,870	$3,900,000	$0	$0
2	$600,000	$0	$193,870	$0	$0	$0
3	$600,000	$0	$193,870	$0	$0	$0
4	$600,000	$0	$193,870	$0	$0	$0
5	$600,000	$2,160,000	$193,870	$0	$0	$0
6	$600,000	$2,160,000	$193,870	$0	$0	$0
7	$600,000	$2,160,000	$193,870	$0	$0	$0
8	$600,000	$2,160,000	$193,870	$0	$0	$0
9	$600,000	$2,160,000	$193,870	$0	$0	$0
10	$600,000	$2,160,000	$193,870	$0	$0	$0
Total	$20,898,700			$3,900,000		

Fig. 1. 10-year cost comparison for traditional washing and HVIC application

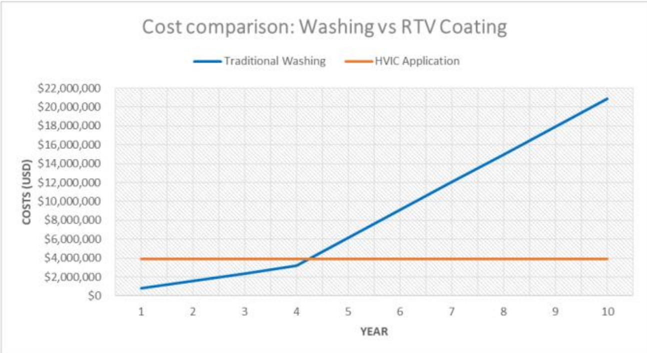

Fig. 2. 10-year cost comparison trendline

ACKNOWLEDGMENT *(Heading 5)*

The preferred spelling of the word "acknowledgment" in America is without an "e" after the "g". Avoid the stilted expression "one of us (R. B. G.) thanks ...". Instead, try "R. B. G. thanks...". Put sponsor acknowledgments in the unnumbered footnote on the first page.

REFERENCES

[1] Research Gate. Mohammad Ali Talebi, "Technical & Economical Evaluation of Using Silicone Rubber RTV Coating for HV Substation in Polluted Area," February 2005.

[2] Virginia Tech. Mona Ghassemi, "Investigating why accelerated insulation degradation is increasingly the reason for power system failures," 2020.

[3] Corus International Projects, "HVIC Lifetime Cost Analysis" – Case Study, March 2007.

[4] IEEE Std. 1523, IEEE Guide for the Application, Maintenance and Evaluation of Room-Temperature Vulcanizing (RTV) Silicone Rubber Coatings for Outdoor Ceramic Insulators, 2018

[5] IEEE Std. 957, IEEE Guide for Cleaning Insulators, 2005