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Improvement of Electrical Performance for Porcelain Insulators Using Silicone Rubber Coating

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Abstract: This work presents the effect of room temperature vulcanized (RTV) silicone rubber coating on cap and pin type porcelain insulator under ac (50Hz) flashover voltage (KV). Describes experimental results obtained for improvement of porcelain insulator removed from 33kV overhead transmission line at Aswan, Egypt after 28 years of service. Also, this study briefly surveys the environmental contaminated surface of porcelain insulator. The flashover voltage have been measured for insulator under various contaminated materials such as ; (cement – sand – silica fume – phosphate). This work concluded that RTV silicon rubber coating register good electrical performance under dry, wet and wet with 5% , 10% NaCl conditions.

Keywords: Flashover voltage, Porcelain insulators, Silicone rubber, Coating, Environmental Contaminated.

I. INTRODUCTION

High voltage insulator plays an important role in an electrical power system including generation, transmission, and distribution of electricity. In addition to the mechanical support of the conductor their electrical role is to isolate the metal structure of the tower from the conductor which carries the power to be transmitted and distributed. As a result, many pollutants from different sources such as dust from industrial factories, saline from the sea and sand storms, may be deposited on the surface of the insulator. Contaminated high voltage insulator in presence of humidity due to fog and rain leads to leakage current, dry band arcing, and ultimately may cause full flashover, which result in power outage and associated cost. Inorganic materials such as porcelain have been used in outdoor insulators for a long time. Porcelain is still the most widely used outdoor insulating material for high voltages [1-5]. Porcelain is an inert and stable material that can take substantial amount of arcing without serious surface degradation, because of their capacity to withstand the heat of dry band arcing. However, these materials are highly wet table when exposed to wet conditions, like fog, dew, and rain, because of their high surface energy [6-10]. The main problem with porcelain high voltage insulators is that water readily forms a continuous film on their surface. In the presence of contamination, leakage current then develops which may lead to flashover that could be followed by an outage of the power system. In order to reduce the incidence of insulator flashover, room temperature vulcanizing (RTV) silicone rubber is being widely used to coat insulators to enhance their electrical Performance[11-15]. .

RTV silicon rubber coating is 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 convenient application is another advantage that affect significantly on cost [16]. Wetting characteristics of various kinds of insulators has been studied. It can be found anti-contamination insulators on the wetting characteristics, such as, polymer and room temperature vulcanized silicone rubber coated insulators having superior hydrophobicity, and semiconducting glaze insulators having drying effect by leakage current in the glaze, have been developed. However, such superior performances of these insulators cannot be always expected [17]. Hydrophobicity of silicone rubber and drying effect of semi conducting glaze may not be fully effective under some wetting conditions. Higher surface resistances were confirmed on RTV silicone rubber coated and semi conducting glaze insulators compared with normal porcelain insulators under clean surface conditions due to hydrophobicity or drying effect in an artificial fog chamber. Higher resistances were measured on RTV SIR coated insulators compared with normal insulators. So, under moderate wetting conditions hydrophobicity may be effective for improving surface insulation [18-19].

This study briefly surveys the polymeric materials RTV silicone rubber coating of porcelain insulator to with stand the flashover ac (50Hz) voltage. Four types of environmental contaminated materials have been introduced on the surface of coated porcelain insulators, such as; sand, cement silica fume and phosphate at dry and wet conditions.

II. SET UP THE TEST

A. Material Specimen

This study was under taken to evaluate the effects that aging and different environmental have had on the

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electrical performance of 33kV high voltage porcelain suspension insulator removed after 28 years of service from EL SRAGE substation to irrigation station, Aswan, Egypt.

Figure.1 illustrates photograph of tested porcelain insulator, cap and pin type model M-HA610BX- E15, and which has been in service since 1986.

Fig. 1: A photograph of the porcelain insulator has been in service since 1986.

B. Porcelain Insulator Parameters

The examined cap and pin type porcelain insulator are used for suspension of 33kV overhead transmission lines. Creepage distance details and parameters of the tested porcelain insulator shown in figure (2).

Fig. 2: A photograph of cap and pin type porcelain insulator's creepage distance (C).

The parameters of the cap and pin type porcelain insulator is shown in figure 3 the parameters: are diameter (D), the height (H) and creepage distance (C).

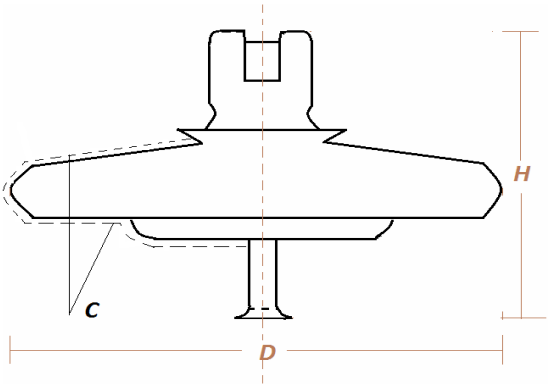

Fig. 4: Parameters of the tested porcelain cap and pin type insulator.

C. Specification of Porcelain Specimen

Table1 shows the specification of cap and pin type porcelain insulator which has been tested

NO	Specifications	
1	Type of insulators	Cap and pin
2	Material used for insulators	Porcelain
3	Color of disc insulator	Brown
4	Rated voltage in kV	12
5	Working of voltage in kV	33
6	No. of sheds in string	3

D. RTV Silicone Rubber Coating

All RTVSR coatings are made of Polydimethylsioxane (PDMS) polymer figure (4). PDMS is the basic polymer; silicone composed of methyl groups, silicon and oxygen. The hydrophobic methyl groups are hydrophobic silicone, and are responsible for water repellency to form drops covering a minimum area. Therefore the coated surface is able to resist the development of leakage current.

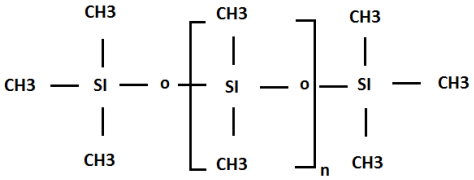

Fig. 3: Chemical formula of PDMS

E. Test Conditions

Cap and pin type porcelain insulators were tested to determine the flashover voltage (kV) under dry, wet, wet with 5% -10%NaCl and environmental polluted conditions before and after coating with RTV silicone rubber.

F. HVAC (50Hz) Test

The ac (50Hz) high voltage obtained from a single phase high voltage transformer (150kV- 15kVA). The output voltage of a transformer is controlled smoothly by a (0-250 v) variac, which regulates the voltage applied to its primary winding. A water limiting resistor is connected between the high voltage power supply and the high voltage transformer, the high voltage set up has been enclosed in an earthen cage .The power supplies connected in series with three sheds suspension insulators made of porcelain. Figure (5) shows the flashover voltage test arrangement.

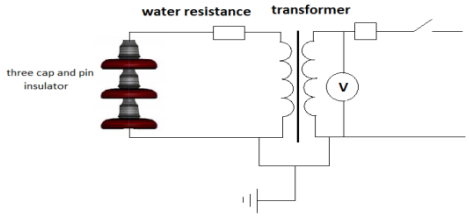

Fig.5*:* Schematic diagram of flashover voltage test arrangement

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G. Test Procedure

Three specimens of cap and pin type porcelain insulators are used in each test to check the reproducibility of the results. The voltage was gradually increased at an almost constant voltage of 2kV/sec. until the breakdown occurs. Flashover voltage is defined as the maximum voltage that the insulating gap with stands just prior to it collapse to a very low voltage compared with a large arc current.

III. TEST RESULTS AND DISCUSSION

The ac (50Hz) flashover voltage has been measured for cap and pin type porcelain insulators under various testing conditions such as; dry, wet, wet with 5% and10% NaCl and environmental polluted conditions (sand, cement, silica fume and phosphate). All porcelain insulators have been tested before and after coating with RTV silicone rubber. During the flashover voltage test, three basic type of experiments were conducted. First, the test of single porcelain insulator was examined. Second, the testes of strings with (two units and three units) of porcelain insulators were determined. .

A. Flashover Voltage at Dry Test condition

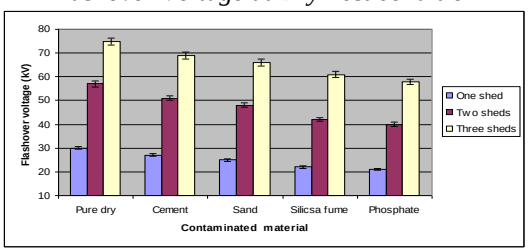

Fig. 6: Flashover voltage (kV) for one, two and three porcelain sheds at dry condition under various contaminated materials

Figure 6 illustrates the testing values of the flashover voltage by using one shed, two sheds and three sheds of porcelain insulators with different contaminating materials such as cement, sand, silica fume and phosphate at dry weather condition. Figure 6 shows the relationship between flashover voltage (kV) against contaminating materials for porcelain specimens at one, two and three sheds of a porcelain insulator. It can be seen from this figure that, the values of flashover voltages (kV) varying according to contaminating materials. For example the highest flashover voltage (kV) can be obtained at dry condition; it reached to 30, 57 and 75 kV at one, two and three sheds, respectively. The flashover voltage (kV) decreased when porcelain specimens coated with any type of contaminating materials. From this figure it can be shown that, the highest values of flashover voltage at cement contaminating then sand, silica fume and phosphate. For example, the flashover voltages are 27, 25, 22 and 21 kV for porcelain specimens coated with cement, sand, silica fume and phosphate, respectively for one shed. When the insulator is dry, the leakage current is low because the conductivity of the surface of insulator is low. It can be concluded from fig.6 that, the relationship between flashover voltage via contaminating materials at one, two and three sheds is non linear. The flashover voltages of cement contaminating are reduced with 10% for one shed, 10.5% for two sheds and 8% for three sheds compared with pure dry condition. The flashover voltages of sand contaminating are reduced with 16.6% for one shed, 15.8% for two sheds and 12% for three sheds compared with pure dry conditions. The flashover voltages of silica fume contaminating are reduced with 26.7% for one shed, 26.3% for two sheds and 18.6% for three sheds compared with pure dry conditions. The flashover voltages of phosphate contaminating are reduced with 20% for one shed, 29.8% for two sheds and 22.7% for three sheds compared with pure dry conditions.

B. Flashover Voltage at Wet Test Condition

The flashover voltage (kV) versus contaminated materials such as; cement, sand, silica fume and phosphate for porcelain insinuators, under wet test condition is shown in figure 7. It can be seen from this figure that the flashover voltage are equal to 25, 49 and 65 kV for porcelain insulators at one, two and three sheds, respectively under wet condition. While the flashover voltages are decreased at any type of contaminated materials. For example; the flashover voltages are decreased by almost 8% , 10.2% and 10.8% for one, two and three porcelain sheds respectively, under wet with cement contaminated material. On the other hand, the maximum percentage reduction of the flashover voltages have had under wet with phosphate contamination it reached to 36%, 36.7% and 29.2% for one, two and three sheds, respectively. .

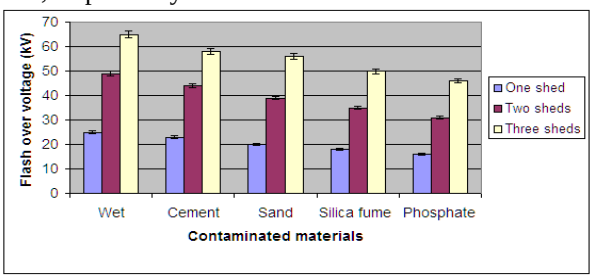

Fig.7. Flashover voltage (kV) for one, two and three porcelain sheds at wet condition under various contaminated materials

C. Electrical Performance of String with Three Porcelain Sheds under Various Wet Salinity

A comparison has been made between the flashover voltage values of string with three porcelain sheds under pure wet, wet with 5% NaCl and wet with 10% NaCl conditions for different environmental contaminated materials in figure 8 for ac (50Hz) flashover voltages. It can be noticed from this figure that, the values of flashover voltages (kV) for string with three sheds at wet condition are higher than that for wet with 5% NaCl and wet with 10% NaCl conditions under all contaminated materials. The values of flashover voltage of string are 65,58,56,50 and 46 kV at without, cement, sand, silica fume and phosphate contaminated materials, respectively under wet condition. While under wet with 5% NaCl condition the flashover voltage values are decreased to 60, 55, 48, 40 and 39 kV for string without, cement, sand, silica fume and phosphate contaminated materials, respectively. At wet with 10% NaCl condition, the values reached to 56,50,41,33 and 31 kV for string without, cement, sand,

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silica fume and phosphate contaminated materials, respectively.

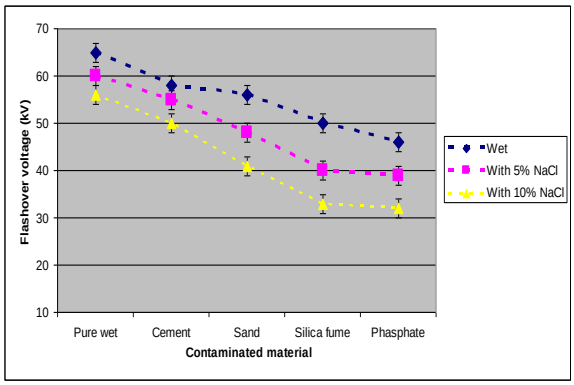

Fig. 8. Flashover voltage (kV) of string with three sheds for various contaminated materials under Pure wet, wet with 5% NaCl and wet with 10% NaCl conditions

D. Effect of RTV Silicone Rubber Coating on Flashover Voltage

Figure.9 illustrates the flashover voltage (kV) of one, two, and three sheds of porcelain insulators after coating with RTV silicone rubber and tested under dry condition with and without espouser to environmental contaminated materials (cement - sand – silica fume – phosphate). From this figure it can be observed that, the porcelain insulator coating with RTV silicone rubber give flashover voltage values as following, 37, 70 and 93 kV at one, two and three sheds, respectively under dry condition without contaminated materials. While the lowest values of flashover voltage can be occurred for porcelain insulator with RTV silicon rubber coating under dry condition with phosphate contaminated. It reached to 27, 49 and 71 kV for one, two and three sheds, respectively.

The same trend has been introduced of flashover voltage (kV) under wet condition for porcelain insulator coating with RTV silicone rubber figure 10. It register 26,55 and 75 kV at one, two and three sheds, respectively under wet condition with RTV silicon rubber coating. Also, flashover voltage are 20,39 and 51 kV at one, two and three sheds, respectively under wet Fig.10.Flashover voltage of porcelain insulators after coating with RTV silicon rubber and exposure to

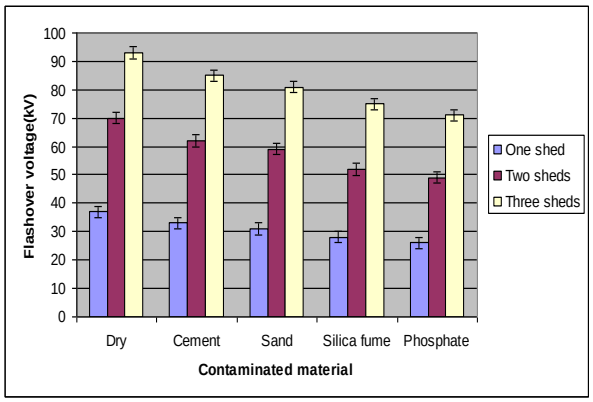

Fig. 9. Flashover voltage of porcelain insulators after coating with RTV silicon rubber and exposure to various contaminated materials under dry condition.

various contaminated materials under wet condition condition with RTV coating for phosphate contaminated.

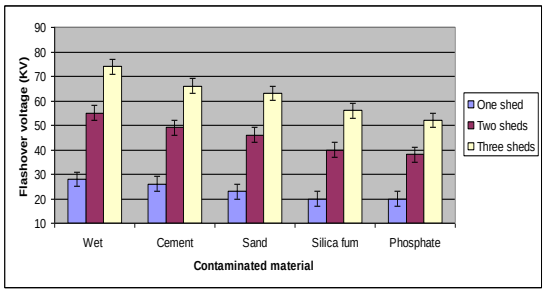

Fig.10. Flashover voltage of porcelain insulators after coating with RTV silicon rubber and exposure to various contaminated materials under wet condition.

IV. GENERAL DISCUSSION AND ANALYSIS

It can be observed from the experimental result that, the ac (50Hz) flashover voltage for porcelain insulator under dry condition is higher than that of pure wet and wet with 5% -10% NaCl conditions. This can be explained due to polymer hydrophobicity. Generally, it can be noticed that, silicone rubber costing is hydrophilic to wet condition with or without NaCl. This mean that all values of flashover voltages decrease at pure wet and wet with 5% - 10% NaCl conditions. But the observed reduction in ac (50Hz) flashover voltage under wet with 5% -10% NaCl condition is lower than that of wet condition, may be explained due to hydrolysis of sodium chloride content in salted water. This results in the formation of sodium hydroxide and evolution of hydrogen chloride gas, which is further dissolved in water. From the experimental results of ac (50Hz) flashover voltage of porcelain insulator, it can be noticed that, electrical performance of porcelain insulator in service since 1986 improved using RTV silicon rubber coating. The values of FOV increase by about 24% in dry condition, 23.2 % in cement, 22.7% in sand, 22.9% in silica fume and 22.4% in phosphate over uncoated insulators. The flashover voltage values of all contaminating materials are increased when coated with RTV in wet conditions. For example flashover voltage increased by about 13.84% in wet condition, 13.79% in cement, 12.5% in sand, 12% in silica fume and 13% in phosphate over uncoated insulators in wet condition. Therefore, RTV silicon rubber coating of porcelain insulators withstands under all environmental contaminated conditions such as; cement, sand, silica fume and phosphate.

V. CONCLUSION

The study on ac (50Hz) flashover voltage properties of cap and pin type porcelain insulators was carried out under various environmental conditions to determine the effects that aging and contamination have had in the electrical performance of porcelain insulators. RTV silicone rubber coating increases the percentage of flashover voltage by almost 24% in dry condition, 23.2 % in cement, 22.7% in sand, 22.9% in silica fume and 22.4% in phosphate than without coating for porcelain insulators removed after 28 years of service. RTV silicone rubber coating is remarked as good adhesive on

the service of cap and pin type porcelain insulators, so it withstands under environmental contaminated conditions such as; cement, sand, silica fume and phosphate.

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