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Advancement and Testing of Silicone Rubber-based Composite Insulators for High Voltage Application, an Overview.

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Abstract - *For many years ceramic and glass insulators were used as high voltage insulators in electric power systems. However, due to their limitations like heavyweight, installation trouble, not operating in highly polluted locations, many researchers were drawn to polymeric insulators and subsequently to their composites. Polymeric insulators were invented in 1963. Polymeric insulators offer enhanced qualities such as decreased weight, more accessible transport, strong vandal resistance, cool installation, high hydrophobicity, and great anti-pollution performance. Because of these features are gaining international appeal and beginning to supplant conventional ceramic and glass insulators. The novel material class Polymer nanocomposites have gained broad attention among electrical experts in electrical power capable of offering considerable property improvements by incorporating nanocomposites. This research discusses the assessment of high-voltage isolators from ceramic to the newest polymer composites and testing of insulator for reliable approach*

***Key Words*: Ceramic, Polymer composite, hydrophobicity nano filler, cycloaliphatic**

1. INTRODUCTION

Past few decades, porcelain and glass have been the primary source for insulators, as shown in fig 1. But it suffers from the disadvantages of being heavy and less water repellent, so attempts are made to create a better alternative for it. Polymer insulators have been developed to address these issues. Advantages of polymer insulators are, very lightweight compared to porcelain and glass insulator, since it is flexible the chance of breakage become minimum, lighter in weight and smaller in size, lower installation cost, higher tensile strength, better performance in polluted areas, imposes less load to the supporting structure; less cleaning is required due to the hydrophobic nature of the insulator. But it has the disadvantage of early aging compared to glass and porcelain insulators, electrical tracking and erosion will develop due to electric discharge. The insulator quality increases with few percent incrementation of micro-nano filler.

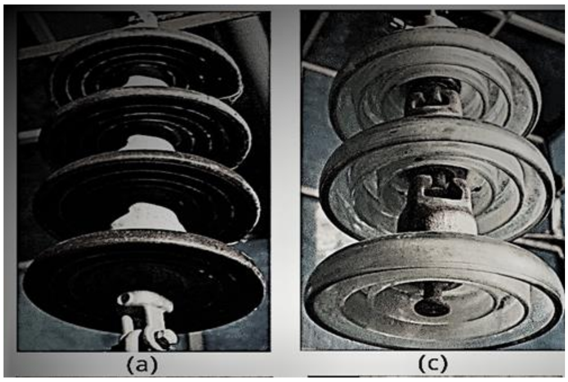

Fig -1: (a) porcelain; (b) glass

2. POLYMERIC INSULATORS

The historical development of polymeric insulators was started in the mid-1940s with epoxy resins manufactured for indoor electrical insulators. The first commercially available polymeric insulators are from cycloaliphatic and bisphenol epoxy resins, as shown in Fig 2 and Fig 3, which were the first-ever polymers used for electrical insulation and in 1950, it was approved in the US and failed shortly after fitting in outdoor environments due to its Substandard Climate resistance. In the year 1963, Cycloaliphatic epoxy was introduced in England for outdoor insulation. Cycloaliphatic epoxy is superior to bisphenol because of its greater resistance to carbon formation. Since then, new CE formulations have resulted in improved electrical performance.

Fig-2: cycloaliphatic epoxy resins
Fig-3: Bisphenol epoxy resins

Later on, from 1960 to mid-1970, Cycloaliphatic epoxy was experimented with bushings of circuit breakers and tested up to 400kV. Today it is used as semi-enclosed system. Seeing the potential of polymer insulators over porcelain, many companies like Ceraver, Ohio Brass, TDL, etc., got tremendous momentum. They started developing and testing Insulators were manufactured with dissimilar matter such as different matter bisphenol, ethyl vinyl acetate (EVA), cycloaliphatic epoxy resins, ethylene, copolymers, Teflon, ethylene-propylene rubber (EPR), ethylene propylene diene monomers (EPDM). The schematic of polymer insulator is shown in fig 4

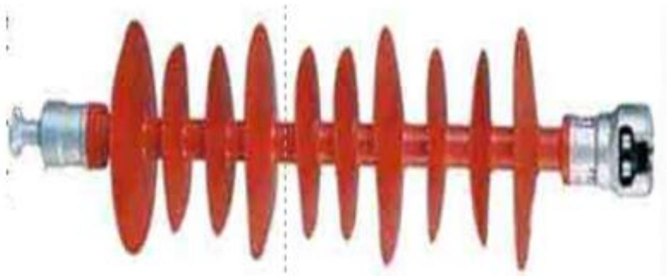

Fig- 4: polymer insulator

In the early 1970s, many countries commence the work of manufacturing outdoor polymer insulator for transmission line, and these are called first-generation polymeric insulators. The early experience was disappointing. Early evaluations indicated compared to porcelain and glass, polymeric insulators have got unique advantages. Like low manufacturing cost, lower transfer cost, finer contamination execution. Several studies were done between 1985 and 2005 to address these concerns, and required improvements were made to the design and material choices. The advancement in the technological improvement has led to the third gen insulator polymer. Additionally, SIR is widely used shed insulators globally because of its superior property

3. SILICON RUBBER

Silicone rubber is widely used polymer insulator material. These Insulator has great water-repellent quality of aquaphobic. SIR has inert and firm performance in the adverse environment condition at high temperature between -55 to +300 degree Celsius thus, an important and superior insulator used these days. for indoor and outdoor HV insulation, surge arresters, and casing pipes. Silicon rubber is classified into three primary forms, curing temperature, and viscosity of the base polymer, based on curing method as shown in fig 5

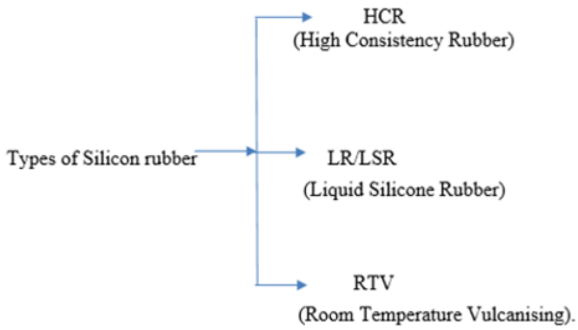

Fig- 5: Classification of silicon rubber

Silicon rubber-based insulators have the excellent water-repelling property called hydrophobicity. This leads to reduction in leakage current and dry band formation; therefore, it performs better in adverse environmental condition Fillers of various sorts may be added to silicone to increase its electrical, mechanical, and thermal qualities.

4. POLYMER COMPOSITE

To enhance the electrical, dielectric, mechanical, and thermal properties of polymer insulators, additional fillers are added in micro-and nano-scales to the base materials to get polymer composite. Fig 6 shows polymer with nano fillers. Lewis [8] wrote an article titled “Nanometric Dielectrics” in 1994 that encouraged polymer nano dielectrics in electrical insulation. Lewis anticipated the physical changes that would occur as a result of nano-inclusion in his work that would enhance electrical insulating applications.

Fig -6: SR Insulator with nano fillers

5. FILLERS

Nanofillers have gained extensive attention for increasing the electrical characteristics of polymer insulating materials. micro-nano scale is obtained by adding filler of dissimilar dimension to the base material. Usually, fillers have a diameter greater or less than 100 nm. Based on dimension nano filler are classified as shown in fig 7.

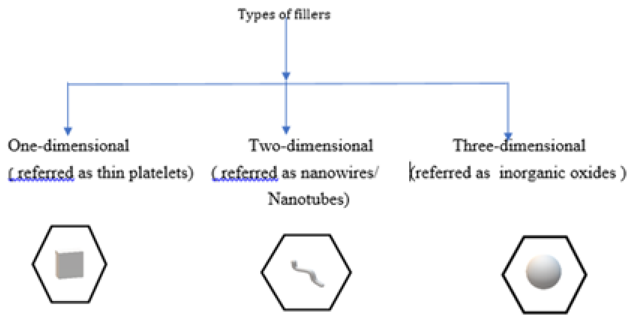

Fig- 7: Classification of fillers

some of the commonly used fillers are ATH, SiO_2, Al_2O_3, TiO_2, ZnO, $CaCO_3$, $BaTiO_3$, Carbon black, Graphite etc., Despite exhibiting good properties, silicon-based polymers suffer from aging by undergoing pressure state. Under practical scenario, insulators are undergone numerous stress together with direct light, high damp extreme temperature and immense applied electric field.

consequently, it loses its properties and this leads to unforeseen flashovers and also insulator breakdown, faults, disturbance in electricity Similarly, for analyzing the aging study of polymer insulator various technique namely, scanning electron microscope, leakage current measurement and inclined plane is used

Types of analysis conducted for actual working habitat for insulator

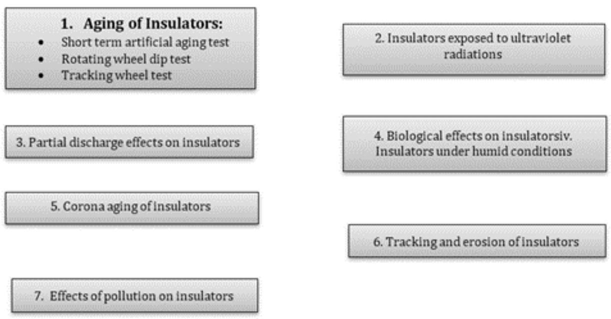

Fig-8: Test and procedures for analyzing insulators

6. CORONA AGING OF INSULATOR

Corona discharges occurring from the metal sections of insulators and the line hardware harm the extended performance of the polymeric insulators and may lead to its ultimate collapse.

Fig- 9: corona discharge on transmission line

The performance of polymeric shed materials exposed to corona stresses in the presence of natural fog conditions findings demonstrated greater surface hydroxylation, consequently leading to higher loss of hydrophobicity. Fig 9 shows the corona discharge.

With the growth in industrialization, there is a rise in the acidic component of the rain and the fog (moisture).

A comparison of the experimental investigations demonstrated that the acidic fog has a more significant influence than the typical fog. This fact has been validated by physio-chemical research such the scanning electron microscopy (SEM) and contact angle measurement. The impact of DC corona is found to be weaker in comparison with the AC, yet the hydroxylation caused by the DC corona in the presence of fog is comparable with that of AC excitement

7. EFFECTS OF POLLUTION ON INSULATOR

The pollution is the main cause for deterioration of the insulator. A contaminated insulator is shown in fig 10. The combination of contaminants and humidity produce short-circuit condition which appears when the insulator loses its resistivity and allow the flow of charges.

Fig -10: Pollution on insulator

The typical phases of a flashover:

- The pollution layer is developed on to the surface of insulator this leads to contamination of insulator
- The climate factor such as rain, fog etc., increase the conductivity of surface. Thus, rise in leakage current

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- The formation of dry bands starts as insulator layer is heated up
- This leads to arcs and this form partial discharge
- Finally, the total discharge is generated.

8. TRACKING AND EROSION OF POLLUTION

The silicone rubber material is commonly employed in high-voltage external insulation systems owing to its outstanding hydrophobicity and hydrophobicity transfer capability. However, silicone rubber is a polymeric material with a low capacity to resist electrical tracking and erosion; consequently, additional fillers must be added to the substance for performance improvements. Tracking and erosion resistance analysis is done by inclined plane test method in which fault is created by submission of material to a various combination of voltage stress and contaminant droplets. This test is time-consuming and challenging to apply in field inspection. novel and quicker technique to test the tracking and erosion resistance performance is presented utilizing laser-induced breakdown spectroscopy (LIBS).

The laser-induced breakdown spectroscopy (LIBS) methodology is an elemental analysis method that causes the sample to create plasma by concentrating an intense pulsed laser onto the sample surface LIBS has been employed in different industries because of its benefits, which include the absence of a sample preparation need, quick measurement speed, capacity to identify practically all components and so on. The LIBS approach has tremendous application potential in high-voltage external insulation detection owing to these benefits and the remote measuring abilities [15] Via LIBS, it is possible to accomplish on-site detection of functioning insulators, which is advantageous for daily operation and maintenance fig 11 shows schematic of LIBS

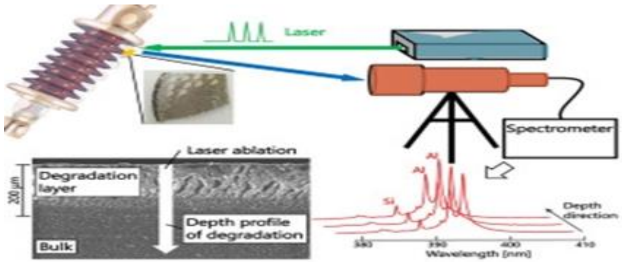

Fig- 11: overview of LIBS

9. ROTATING WHEEL DIP TEST

Rotating Wheel Dip Test (RWDT) conducts aging, that under demanding environment depicts the impact of polymeric insulator samples. The spinning wheel configuration was intended for conventional configuration. The primary goal of redesigning the setup is to analyze materials at a lower budget and test in laboratory settings.

RWDT has four positions:

1) The first position is submersion in saltwater.

2) The second position is a horizontal de-wetting position that allows water to drip off due to hydrophobicity.

3) The third position is an activated position were a high voltage is applied to the sample from the top end, and the peak leakage current is recorded using a current recorder.

4) At the fourth position, the sample is horizontal.

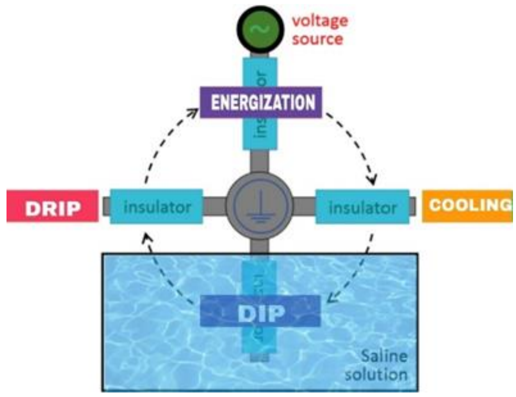

Fig-12: Schematic of rotating dip wheel test

Figure 12 illustrates a schematic illustration of a spinning wheel configuration. It comprises of Four Rotating Wheel Positions.
1. Dipping
2. Dripping
3. Energizing
4. Cooling

10. ARTIFICIAL AGING OF INSULATOR

The procedure for aging of insulator is conducted in a closed chamber.
The test is classed into three types.
1) Laboratory tests
2) Aging in a Multi-Stress Lab
3) Multi-Stress Accelerated Aging in the Lab

10.1 Multi stress aging

Multi-stress aging is similar to natural aging. All the actual stresses are imposed on insulator in a closed chamber. This is the easiest technique to estimate aging, Fig 13 shows lab aging test of insulator

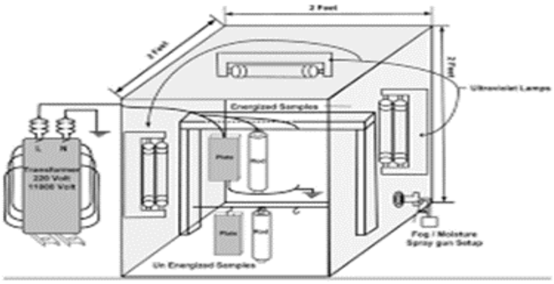

Fig-13: schematic of lab aging of insulator

10.2 Accelerated multi stress Lab aging

This technique follows same as multi-stresses aging but in premeditated manner by artificially simulating sequence of day and night in more rapid fashion.
This technique includes incrementation of temperature, sunlight, UV radiation, in non-linear manner.
This technique recreates the actual field state and produce result similar to the real aging

11. CONCLUSION

Many researchers have made In-depth studies and conducted practical tests on Electrical insulators, which are a critical component of electric power networks that is utilized in substations, distribution and transmission lines. Insulators were originally built of ceramic and glass materials. Polymeric insulators were invented, and subsequent advancements in their design and production have made them more appealing to electrical utilities for use in their composites. In this paper, an attempt is made to discuss an evaluation of high voltage insulators for outdoor insulation. Composite insulators have recently been employed extensively in various large-scale high voltage transmission line installations. Numerous electrical utilities tend to agree that composite insulators outperform ceramic or glass insulators in terms of critical performance characteristics. This review has also identified some challenging aspects, and this could be studied in the future to significantly enhance the life expectancy of silicone rubber-based insulator.

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