A Review Article Optimization of Electric Field Stress on High Voltage Insulator

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Abstract -To reviewstudy the effect of contamination on the insulator upon the tangential field, the simulation charges is replaced by complex charges. The contamination layer is simulated by a uniform surface resistivity along the insulator. The magnitudes of the simulation charges (real and imaginary components) are determined by a fore mentioned concept of error-function minimization. First, the algorithm is developed for calculating the tangential field is explained. Then the method of optimization is discussed, and the effect of contamination on the calculated tangential field distribution is investigated showing how the developed algorithm will accommodate this effect. Finally, the results obtained are discussed.

Keywords-Field Stress, Contamination, Optimization, Insulators, Tangential Field.

I. INTRODUCTION

A high voltage overhead insulator is providing isolation path, which insulates the live conductor from the electrical transmission and distribution tower. The HV insulators play vital parts in the transmission and distribution networks, which are used to transmit the electrical power to the consumers through the power system. The commercial needs for the high voltage lines started in 1880's, which is the most cost effective technique to transmit the electrical energy over long distance. Since then, larger and more efficient overhead insulators are required to carry and support high voltage lines. The primary function of the high voltage insulators is to separate the live conductors from each other and from the utility pole. They also provide mechanical support for the high voltage insulator [1].

The glass and porcelain insulators have been used in the power utilities for over one century. These insulators have good resistance against environmental aging and they have been used in a wide range of applications. However, due to the hydrophilic surface of the ceramic material, the pollution performance of these insulators is poor. In the 1960's, the polymer insulators, which are also referred to as composite or non-ceramic insulators, are introduced to the market. The non-ceramic insulators show many advantages over the conventional insulator, which make them more preferable than the porcelain and glass insulators. Furthermore, they have better hydrophobicity, lower leakage current, resistance to vandalism and higher mechanical strength [2].

The polymer insulators have some weakness, which must be taken into consideration during the insulator design. The life expectancy of the composite polymeric insulators

is difficult to estimate and the reliability of the polymer materials is unknown. Based on field data, the polymer materials are susceptible to degradation under electric field stress, which may lead to early failure. Hence, the performance of the polymeric dielectrics must be tested and the electric field distribution along the overhead insulator must be studied. The existence of intermediate hardware also created nonlinearity of the electric field on the polymeric insulators when compared to conventional insulators. Hence, composite insulators have a certain level of stress field grading. Very high level of electrical field stress can cause electromagnetic pollution, perceptible noise, partial discharge for the system and accelerated aging of the insulator [3].

The fundamental of the electric field and the techniques of controlling the electric field strength and distribution must be considered, in order to understand the behavior of the insulation materials under the influence of AC/DC electric field. Electric field can be described as the electric force experienced by charge at any given point in the vicinity of the field. The electric force of the electric charge rises when the electric field is applied. Insulators, which are also called dielectrics, are materials where charges are not free to move through their body.

However, there is no perfect dielectric because the dielectric consists some conductivity. When a high level of electric field applied over the dielectric, the insulator is heated up and conductive current will begin to flow. Hence, insulators must be tested to identify their withstand voltage level which is called "standard insulation level". If the insulation material exposes to high electric stress over its critical electric field strength, then insulation failures in the form of corona, ionization, or electric arc will occur. These partial discharge

activities will lead to an early breakdown. Electric field distribution also depends on many parameters including voltage waveform, insulator design, shape and materials of the electrodes, tower configuration and atmospheric conditions and pollution [4].

The following sections of this manuscript identify the factors that may increase the electric field strength along the high voltage (HV) insulators. The existing stress control methods and new technologies in stress control using advanced materials are discussed in more details [5].

II. TYPES OF HIGH VOITAGE INSULATOR

There are 5 types of insulators used in transmission lines as overhead insulation:
1. Pin Insulator
2. Suspension Insulator
3. Strain Insulator
4. Stay Insulator
5. Shackle Insulator

1. Pin Insulator

Pin insulators are the earliest developed overhead insulator, but are still commonly used in power networks up to 33 kV system. Pin type insulator can be one part, two parts or three parts type, depending upon application voltage.

In a 11 kV system we generally use one part type insulator where whole pin insulator is one piece of properly shaped porcelain or glass.
As the leakage path of insulator is through its surface, it is desirable to increase the vertical length of the insulator surface area for lengthening leakage path. We provide one, two or more rain sheds or petticoats on the insulator body to obtain long leakage path[6].
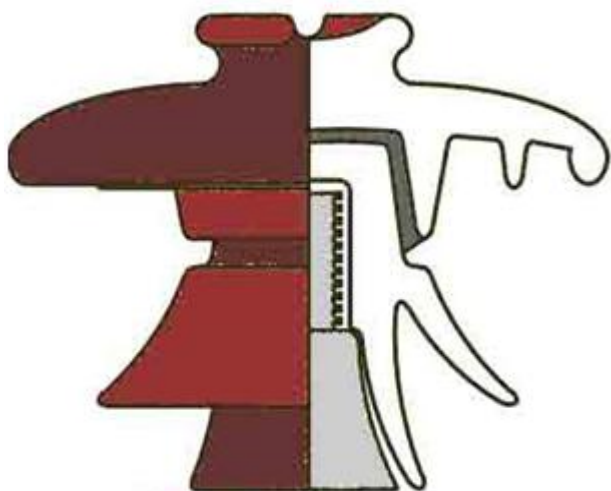

Fig.1.Pin Insulator.

2. Suspension Insulator:

In higher voltage, beyond 33KV, it becomes uneconomical to use pin insulator because size, weight of the insulator become more. Handling and replacing bigger size single unit insulator are quite difficult task. For overcoming these difficulties, suspension insulator was developed.
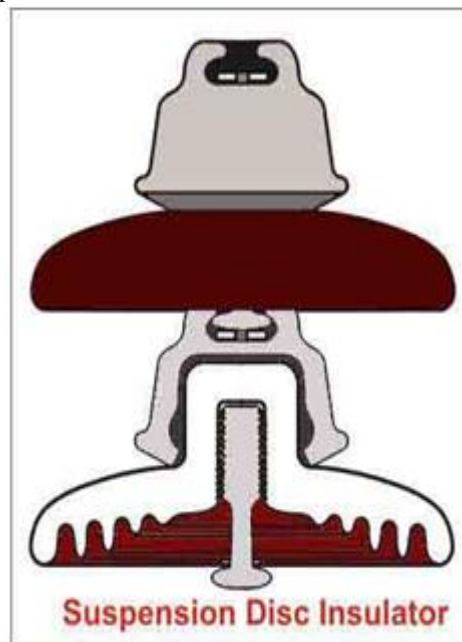

Suspension Disc Insulator
Fig.2.Suspension insulator.

3.Strain Insulator:

When suspension string is used to sustain extraordinary tensile load of conductor it is referred as string insulator. When there is a dead end or there is a sharp corner in transmission line, the line has to sustain a great tensile load of conductor or strain. A strain insulator must have considerable mechanical strength as well as the necessary electrical insulating properties[7].
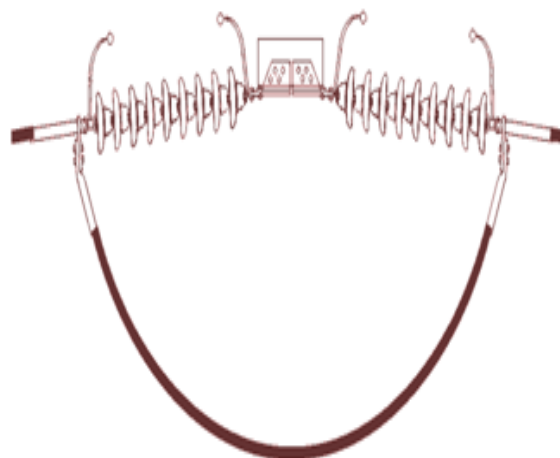

Fig.3. Strain Insulator.

III. PROJECT OBJECTIVE

1.   Effect of Contamination
To study the effect of contamination of the insulators upon the tangential field distribution, the algorithm developed is expanded to treat capacitive-resistive fields as well. The simulation charges were replaced by complex charges. The contamination layer was simulated by a uniform surface resistivity along the insulator.
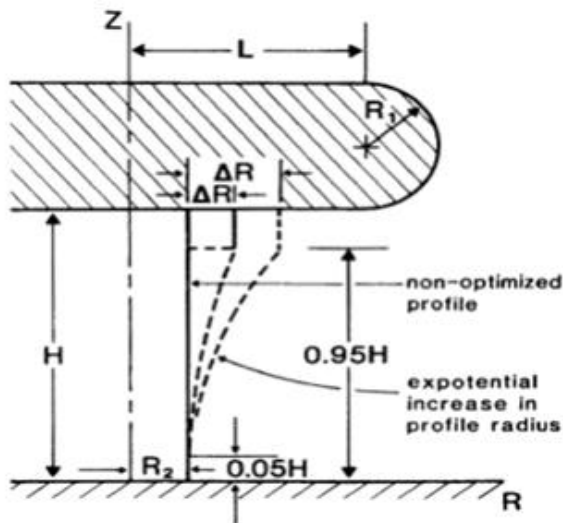

Fig.4.Proposed approach for profile optimization.

Electric stress and temperature effects
1. High voltage $\rightarrow$ high electric stress $\rightarrow$ cause insulation failure $\rightarrow$ short circuit.
2. High temperature $\rightarrow$ gradual insulation deterioration or thermal breakdown.
3. Note also other effects, e.g. mechanical stress, environmental $\rightarrow$ multi-factor ageing

Electric field stress
The electric field intensity E at any location in an electrostatic field is related to the force F experienced by a charge q as F=qE. Moreover, the electric flux density D associated with E is given as D=εE. If the medium is free of any space charge, the electric field is obtained from the solution of the Laplace equation:

$\nabla 2\ \varphi = 0$

Where
φ is the potential which is related to
E and path l through which the charge is moved by

$$\varphi = -\int E.d\ L$$

IV. ISSUES OF OLD ARTICLES

SunithaPremakumar ; Rini Patel ; ApratimAmbade ; H. A. Mangalvedhekar ; Rehim N. Rajan ; R. I. Bakhtsin "Optimization of electric stresses in high voltage system of DC accelerator" Optimization of

electrical stresses is essential to ensure the reliable operation of high voltage systems and it can be achieved by careful design of high voltage electrodes and electrical insulation systems. Improper design of electrodes and insulation can cause excessive electrical stresses in the high voltage system and it will eventually lead to electrical breakdown. DC accelerators employing parallel coupled voltage multiplier scheme requires sufficient capacitances to be developed between a set of electrodes, while ensuring operating electrical stresses within the safe limits.

The electric field intensity in the system will depend on the applied voltage and also on the geometry of electrodes and insulators. Shape, size and location of electrodes and insulators need to be optimized to maintain the maximum electric field. This paper describes the analysis and simulation done for optimization of electrical stresses in the systComputer Simulation Technology - Electromagnetic (CST EM) Studioem by optimizing the Radio Frequency Feeder Electrodes of an industrial electron accelerator being developed at BARC. Computer Simulation Technology - Electromagnetic (CST EM) Studio has been used for this study.

M. Abdel-SalamE.K. Stanek "Optimizing Field Stress on High-Voltage Insulators" A method is described for optimizing the field stress on HV insulators by modifying their profile, seeking a uniform distribution of the tangential field among the insulator surface. This results in an increase of the onset voltage for surface flashover and in a significant saving of the space of the HV installation. The optimization process was achieved by an algorithm developed for calculating the tangential field Component and mathematical expressions of the profile to be corrected through an iterative procedure. The algorithm was based on a modified charge-simulation technique to satisfy a better matching of the boundary conditions to the electrode and insulator surfaces involved in the HV installation. The algorithm is expanded to study the effect of contamination on the tangential field distribution. It is found that the higher the conductivity of the contamination layer, the higher is the field uniformity along the insulator surface[7,8].

N. MuruganG. Sharmila "Design optimization of high voltage composite insulator using Electric field computations" In power system, the consistent power supply plays a vital role in generation, transmission and distribution. It is necessary to aid uninterrupted power supply by continuous monitoring of power apparatus. Mainly insulators are the integral part of the power system. Among them composite insulators are essential for the better performance. One of the major factors governing the electrical performance of composite insulator is characterised by its field distribution along their length. In this paper, an attempt has been made to

analysis the factors affect the Electric field (E-field) distribution are discussed. The analysis are performed by designing a different configuration of metal end fittings in composite insulator and compared their results and shows which configuration shows better performance under normal conditions, because end fitting dimension is one of the major factor that govern the characteristics of the composite insulators. Furthermore to improve the electric behaviour of the composite insulators grading material is introduced. The main objective of this work is to improve the electric field distribution of composite insulator, in order to enhance the long term performance of insulator. An 11kV composite insulator is modelled by using COMSOL MULTIPHYSICS software that performs two dimension (2D) and three dimension (3D) finite element method to investigate the E-field distribution.

Ammar Al-Gheilani, Wayne Rowe, Yongxiang Li, Khoi Loon Wong "Stress control methods on a high voltage insulator: A review" This review article provides a comprehensive overview of the many factors that may enhance the level of electric field along the high voltage (HV) insulators, review of existing stress control methods and new promising technologies in stress control using advanced materials. In the first section, the factors that could possibly raise electric field stress around the HV insulators are discussed. Localized field enhancement, especially in the area close to the high voltage potential and ground potential will accelerate the degradation and subsequently causing pre-mature failure of the insulating material.

Other than electrical field enhancement, mechanical stresses and environmental impacts also affect the performance of the high voltage overhead insulators. Consequently, multi-facet approaches are required to improve the HV insulators performance and reliability over their service life. In the second section, the existing stress control methods that include corona ring, combined insulation assembly and end-fitting design are reviewed. In the final section, a new promising technology of stress control using field grading methods (resistive and capacitive) is presented. Field grading material (FGM) is a new technology where the inorganic fillers are added to the insulation host matrixes to enhance the mechanical and electrical performance of the insulation. FGM shows superior electrical performance compared to the conventional insulation material, which is also discussed in this paper.

Krutika T. Agrawal , P. C. Tapre , C. Veeresh "Electric Field Stress Calculation on High Voltage Insulator" A method is described for optimizing the field stress on HV insulators by modifying their profile, seeking a uniform distribution of the tangential field along the insulator surface. This results in an increase of the onset voltage for surface flashover and in a significant

saving of the space of the HV installation. The optimization process was achieved by an algorithm developed for calculating the tangential field component and mathematical expressions of the profile to be corrected through an iterative procedure. The algorithm was based on a modified charge simulation technique to satisfy a better matching of the boundary conditions to the electrode and insulator surfaces involved in the HV installation. The algorithm is expanded to study the effect of contamination on the tangential field distribution. It is found that the higher the conductivity of the contamination layer, the higher is the field uniformity along the insulator surface.

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