Simulation of Structural, Thermal and Electrical Load for High Voltage Ceramic Cap and Pin Disc Insulator Assembly

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ABSTRACT

This paper studies mechanical- stress-strain, thermal- temperature distribution, electrical potential and electric field distribution for 11 kV, single ceramic cap and pin disc insulator assembly used for high voltage transmission and distribution systems. The coupled field finite element computer simulation is carried out by using a commercially available software package, which allows quantifying the effects of insulator assembly on where structural, thermal and electrical load distribution considered simultaneously. The simulation result shows stress concentration due to application of structural, thermal, and electrical load. The stress was maximum on pin and moderate on sealing material and disc. Similarly in electrical analysis, nodal electrical potential and electrical field distribution observed decreasing from bottom pin of insulator assembly to top cup end of insulator model. Remarkable stresses, temperature, electrical potential and electrical field rise was not observed at porcelain but mainly observed in critical areas like triple junction (pin-porcelain, porcelain-cup junction of insulator assembly), despite high tension, high temperature of conductor and high voltage-current. With continuous use of an insulator and varying environmental condition, this high tension, temperature and high voltage may cause small crack in sealing material and the insulator disc material. This may reduce performance or cause failure of an insulator without any prior notice.

Keywords: Ceramic Insulator Assembly, Electric Charge Distribution Load, Finite Element Analysis, Structural Load, Thermal Load

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INTRODUCTION

Literally insulator means a substance that blocks or retards the flow of electrical or thermal current. Obviously, the insulator that we talk about here is an electrical insulator because it is used to block or retard electrical current. Thus outdoor insulator is the insulator for outdoor application. Electric power delivery from generation site to consumer uses overhead conductors for long transmission. Conductors are mostly operated at high voltage in order to minimize losses during transmission and distribution, and it also needs support along the way to keep it at certain height and to keep it isolated from earthed supports. Insulators play major role to isolate conductor from the support and also used as a support of the conductor itself. Therefore, they must have good insulation properties and should be mechanically strong. Transformers (power and instrument), circuit breakers, and arresters also use similar insulators as bushings and they also provide both mechanical and electrical strength. Insulators protect the more expensive apparatus involved in power system. They act as first protection and have to fail first when over-voltages propagate along the line. They need good electrical and mechanical performance in order to withstand wide range of conditions that occur. These conditions include environmental, mechanical and electrical stress on the insulator.

Unfortunately, the combinations of many variable environmental parameters which influence an insulator’s behavior over its lifetime are difficult to artificially simulate. The detection and replacement of faulty insulators on power transmission lines is of great importance for the safe operation of power system. Appropriate shape and dimension of insulators in electrical equipment must provide sufficient mechanical and electrical strength and the required minimum stress-strain, minimum effect of temperature and minimum insulation resistance during the whole lifetime of insulator. Standardized dimensions and shapes rules could support designers if they give minimum insulation distances for a given failure risk. This requires different shapes of an insulator and environmental service conditions of electrical equipments. The main concern of subsequent insulation design is the steady-state voltage strength, flashover, impulse and mechanical tension/compression, temperature developed at pin and conductor interaction etc. This requires the knowledge of mechanisms leading to insulation failure and its dependency on material, shape, dimension of an insulator, electrode spacing and voltage etc. A great number of projects were carried out and many studies have been published all over the world concerning the various loads like high tension, temperature and voltage-current and their effects on performance and failure of insulator. However these affects i.e. structural, thermal and electrical have been studied on individual basis only. That is only one effect is considered at a time, however in the real field these effects should be considered simultaneously for the complete analysis of insulator and insulator assembly since these three effects are present at the same time. In spite of these significant efforts it has become evident that there is no fully acceptable explanation of the performance and failure of an insulator.

J. J. Taylor and A. D. Lantz (1960), P. J. Lambeth et al. (1970), R. Cortina and J. P. Rynders (1981), in their papers presented that, insulators are continually subjected to mechanical and electrical stresses which depend on the characteristics of line. These stresses become critically high under exceptional environmental conditions. The choice of the insulator must be made by considering: The characteristics of electrical network, degree of reliability, accepted limits of inconvenience operation, environment and effects of aging on the insulator. Recently, (Kontargyri, et al., 2004), has studied the computer aided numerical methods like FEM, FDM and BEM. Using numerical methods, the mechanical and electrical characteristics of ceramic material affected by the force, tension, temperature and electrical load can be easily evaluated.

Fujii, Mizuno, and Naito (2007) investigated the temperature rise of transmission line insulators when the current carried by the line
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