Coupled Field Thermoelectric Simulation of High Voltage Ceramic Cap and Pin Disc Type Insulator Assembly

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ABSTRACT

Transmission of high power at high voltages over very long distances has become very imperative. At present, throughout the globe, this task performed by overhead transmission lines. The dual task of mechanically supporting and electrically isolating the live phase conductors from the support tower is performed by insulators. The electrical potential, field and temperature distribution along the insulators governs the possible effects, which is quite detrimental to the system. However, a reliable data on electrical potential, field and temperature distribution in commonly employed insulators are rather scarce or access individually for thermal or electrical load only. Considering this, the present work has made an attempt to study accurately, thermal and electrical characteristics of 11 kV single cap and pin type ceramic disc distribution insulator assembly used for high voltage transmission. The coupled field thermo electrical finite element by using commercially available FEM software Ansys-11 is employed for the required field computations. This new set of ANSYS coupled-field elements enables users to accurately and efficiently analyze thermoelectric devices. This paper review the finite element formulation, which in addition to Joule heating, includes Seebeck, Peltier, Thomson effects and electrical load, i.e. by considering thermal and electric loads acting simultaneously. The Electrical voltage, electrical field and temperature distribution is deduced and compared with various other/individual analyses.

Keywords: Cap and Pin Type Ceramic Insulator Assembly, Charge Distribution Load, Coupled Field Thermo-Electric, Finite Element Analysis, Thermal Load, Electric

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INTRODUCTION

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 an electrical current. Thus outdoor insulator is the insulator for outdoor applications. Electric power delivering from the generation site to the consumer uses overhead conductors for long transmission. Conductors are mostly operated at a high voltage in order to minimize losses during transmission and distribution and it also needs support along the way to keep it at a certain height and to keep it isolated from earthed supports. Insulators have a major role to isolate the conductor from the support. They are also used as a support of the conductor itself. Hence, they have to have good insulation properties and also be mechanically strong. The insulator itself has a role to protect the more expensive apparatus involved in the power system. They act as the first protection and have to fail first when overvoltages propagate along the line. They need a good electrical and mechanical performance in order to withstand the wide range of conditions that occur. These conditions include the 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 artificialy simulate. To detection and replacement of faulty insulators on power transmission lines is of a great importance for the safe operation of the power system. An appropriate shape and dimensioning of insulators in electrical equipment must provide a sufficient thermal and electrical strength and the required minimum effect of temperature and insulation resistance during the whole lifetime of insulator. Standardized dimensions and shapes rules could support the designers if they give minimum insulation distances for a given failure risk. The main concern of the subsequent insulation design is the steady-state voltage strength, flashover, impulse, electrical potential, field, and temperature developed at pin and conductor interaction etc. This requires knowledge of the mechanisms leading to insulation failure and its dependency on material, shape of an insulator, dimension of an insulator, electrode spacing and voltage etc.

Power utility companies are requested to transmit more power to meet the growing demand. However, it is difficult to construct new transmission lines from economical and environmental points of view. Considering such circumstances, upgrading of the capacities of existing lines seems a solution to meet the requirement. Up-grading the line voltage of existing transmission lines results in some technical problems. It is thus very necessary to investigate the possibility of increasing the current carrying capacities of the lines. Stability, voltage and other factors need to be considered in the determination of the current carrying capacity of a conductor. Y. Mizuno et al. (1998) reported that the current carrying capacity of a conductor is principally militated by its thermal limits. Namely, sag, loss in tensile strength of conductor, the degradation at the conductor joints and or compression clamps, etc. are all thermal limiting factors. K. Adomah, et al. (2000), reported that the tolerable sag and loss in tensile strength for the existing aluminum conductor steel reinforced (ACSR). The simulation based on probabilistic approach using actually recorded climatic data when the current capacity of the conductor is increased. Conventional ACSR type conductor is typically operated at temperatures up to 75°C. The mechanical strength of the conductor is provided by both the steel cable and the aluminum conductor, which changes properties above about 95°C. In this case the steel cable provides all of the mechanical strength, and the temperature limits are based on the characteristics of the steel core rather than the aluminum conductor. ACSS conductor is rated for continuous operation at 200°C, with some types available for use at 250°C. Operation of conductors at these high temperatures will obviously result in higher