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A study of electrical stress grading of composite bushings by means of a resistive silicone rubber coating

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Abstract

Local discharges in the vicinity of the mounting flange of composite bushings due to the electric field enhancement can cause insulating material degradation and finally lead to failure. In this paper, a proposed solution to this problem by employing a resistive silicone rubber coating on composite HV bushings was investigated. Finite Element Method (FEM) analysis of the electric field distribution along the surface of bushings by FEMLAB® simulation and potential measurements by an electrostatic probe (ESP) technique confirmed that the stress grading effect of a 100 MΩ resistive coating results in a linear potential distribution and the tangential field is significantly reduced in the region of the mounting flange.

Keywords: Stress grading; Electrostatic probe; Finite element method; Electric field distribution; Silicone rubber; Composite bushing

1. Introduction

The role that bushings play in power systems subjects them to high electrical, mechanical, and environmental stresses; hence bushings are the most vulnerable components of major apparatuses.

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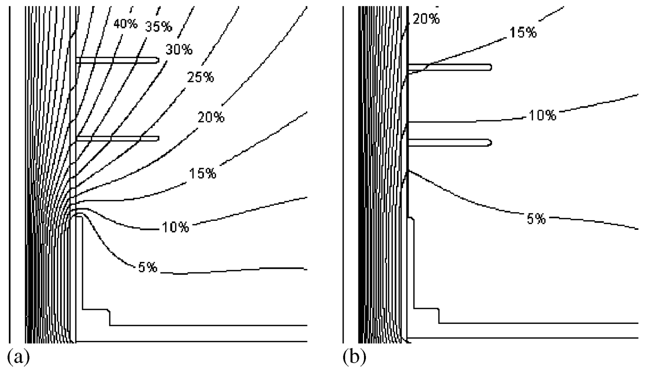

Fig. 1. (a) Equipotentials of bushing with no stress grading; and (b) a resistive silicone rubber coating.

Electrical stresses include the steady-state power frequency nominal operating voltage, and transient over voltages imposed by lightning and switching operations. Excessive electrical stress on insulators can cause local discharge, flashover or puncture, and further, lead to the system failure. In addition, parts of bushing insulations are subjected to high electrical stress, for example, at the vicinity of the mounting flange, which are referred to the "hazard area" as shown in Fig. 1(a).

In this region, the local electrical field can exceed the dielectric strength of air resulting in corona discharge. Ozone or oxides of nitrogen (NO_x) are formed and may react with the insulation. Both the chemical reactions and physical action of surface discharges contribute to material aging. When bushings are in areas where they are exposed to contamination, their performance can deteriorate significantly. Therefore, stress control is a main concern of bushing design.

Several approaches such as use of grading rings (corona rings), floating shields (e.g. condenser bushings), high permittivity insulation materials, and resistive layers or glazes are essential to achieve stress control [1,2]. Among these, the resistive glaze is an effective method that is adopted on porcelain insulators as referred to RG insulators [3], but no such solutions are available for composite bushings as the process of making resistive glaze onto organic material such as silicone rubber is infeasible.

In this study, a resistive silicone rubber (RSR) was developed and applied to the surface of 69 kV composite bushings as the stress grading layer. The conduction is achieved by virtue of the interconnected conductive particles forming resistive networks, which allow the flow of leakage current through the conducting path. As such, the potential distribution along the bushing surface is dominated by these resistive networks.

2. Stress grading material—resistive silicone rubber

The RSR stress grading material is formulated from a two-part room temperature vulcanizing silicone rubber (RTV) loaded with a sufficient amount of semiconductive