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A Study of Surface Conductivity and Flashover Voltage of Ice Samples Formed Under Various Freezing Conditions

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ABSTRACT

The present paper investigated surface conductivity and flashover voltage of cylindrical atmospheric and ordinary ice samples. The influence of the surrounding air temperature and the conductivity of freezing water on maximum withstand voltage and surface conductivity of ice samples were studied. The variations in temperature within the bulk ice, on outer and inner ice surfaces, caused by the variations in surrounding air temperature were also examined. The results obtained will lay a foundation for establishing a mathematical model for the criteria of flashover on ice-covered insulators.

INTRODUCTION

Ice accretion on outdoor insulators causes a substantial decrease in the withstand voltage, sometimes leading to flashover and occasional outages (Kawai, 1970; Farzaneh and Melo, 1990; Matsuda et al., 1991; Fikke et al., 1992). The major effects of ice on insulator characteristics are a decrease in the leakage distance and an increase in surface conductivity leading to a high possibility of flashover occurrence under service voltages (Farzaneh et al., 1994). Most of the published studies on the flashover performance of ice-covered insulators, up to the present, have concentrated on determining the withstand voltage (Phan and Matsuo, 1983; Vuckvic and Zdravkovic, 1990; Matsuda et al., 1991). Very few in-depth studies are available on electrical discharge on ice surfaces or the mechanisms involved.

The presence of ice on the insulators is sometimes considered to be a special type of pollution (Sun et al., 1989; Farzaneh et al., 1994). With this in mind, AC flashover along ice surfaces may therefore be analyzed using the pollution discharge model which involves the following equation:

$$V_m = AxI_m^{-n} + R(x)I_m \quad (1)$$

where V_m and I_m are the peak values of the alternating applied voltage and leakage current respectively; A and n are the arc constants; x is the length of the arc; and $R(x)$ is the surface resistance of the part of the ice which is not bridged by the arc. The determination of A, n and R is essential for the analysis of the discharge and arc development on the surface of the ice.

Resistance R is perhaps one of the most important parameters influencing ice surface flashover. The variation of R is more complex for iced surfaces than for insulator surfaces polluted by salt (NaCl). First, the type of ice formed is influenced by the freezing process (Farzaneh and Kiernicki, 1995). Second, there are two discharge surfaces for ice-covered insulators as compared to only one surface for polluted insulators: the outer ice surface and the interface of ice and insulator. Flashover along the interface of ice and insulator has frequently been observed in our laboratory investigations. Third, the surface conductivity of ice is influenced by a large number of parameters such as surrounding air temperature (Phan and Matsuo, 1983), water conductivity (Farzaneh and Drapeau, 1994) and icing process. All these complex intervening parameters make it difficult to establish a mathematical model based on the experimental flashover results obtained from a string of ice-covered insulators. The use of ice cylinders in laboratory investigations provides useful results for establishing such a mathematical model.

The present study focuses on determining the values of surface conductivity of ice samples and their influence on the maximum withstand voltage using a simple cylindrical ice sample formed from supercooled droplets or from the freezing of water. The experimental results obtained will be used as basic data to establish a mathematical model for analyzing flashover along ice surfaces.

ICE SAMPLES AND FACILITIES USED

Under actual conditions and depending on wind direction and atmospheric conditions, ice is accumulated either partially or wholly on the insulator string surface, forming roughly on the

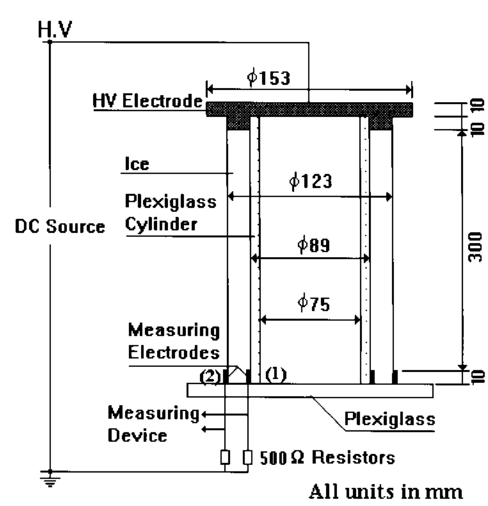

Fig. 1 Ice sample and test circuit

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KEY WORDS: Ice-covered insulators, surface conductivity, flashover.