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Flashover Performance of Insulators in the Presence of Short Icicles

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ABSTRACT

This work chiefly presents the results of a laboratory investigation of ac leakage current and ac flashover on a short insulator string. The string was partially iced with supercooled droplets at -1.5°C simulating a rime fog, this being one of the factors responsible for a large number of flashovers on Ontario Hydro's 500 kV system in March 1986. It was found that the leakage current of insulators in the presence of short icicles was very small and consequently no flashover occurred under normal line-to-ground voltage applied to the insulators. Flashover was produced only under an applied voltage about 80% higher than normal voltage. It was concluded that the presence of fog was associated with the flashovers occurring in March '86, but that other parameters such as insulator surface contamination and water condensation were also active factors contributing to these flashovers.

INTRODUCTION

Ice accretion, together with superimposed contamination, often causes a decrease in the flashover voltage of outdoor insulators, resulting in occasional outages. Insulation failures due to the ice-bridging of insulators are reported from the USA (Kawai, 1970), Canada (Melo et al., 1988), Japan (Matsuda et al., 1991), Norway (Fikke et al., 1992), China (Shu, 1991) and a few other countries.

Ice is generally accreted during periods of sub-zero °C temperatures by the impact of supercooled droplets on the surface of the insulators. Depending on the atmospheric conditions and the heat transfer between the impinging water droplets and the insulators, ice is basically formed in a dry or a wet regime. In a dry regime, all the droplets impinging on the surface of the insulators are completely frozen and there is no run-off. The temperature of ice deposition in dry growth is below 0°C and ice formed is porous and opaque (Macklin and Payne, 1967). Due to the absence of icicles, which are filled with liquid water at the tip during their formation (Makkonen, 1988; Farzaneh and Laforte, 1992), and a water film at the surface of the ice accretions, the withstand voltage of the insulators stays high enough and flashover does not occurr under normal voltage (Phan and Matsuo, 1984). Contrary to dry growth regimes, wet growth processes involve the loss of unfrozen water forming the bulk of the ice deposit on the surface and icicles around the skirts of the insulators. This type of accretion, with a density of 0.87 $g.cm^{-3}$ and known as wet ice (Farzaneh and Laforte, 1992), is the most severe type of ice, because of its association with the highest probability of flashover. Wet ice and all other types of atmospheric ice may be accreted during freezing rain, drizzle, incloud riming, rime fog and condensation.

In the present paper our attention is directed to the accretion of fog on insulators. This was associated with a large number of flashovers on Ontario Hydro's 500 kV lines on March 10, 1986. These events were preceded by a long period of subzero fog, followed by light freezing rain and rising temperatures (Boyer and Meale, 1988). Insulator flashovers in the past — similar to March 10, 1986 — have been associated with ice bridging, where a large amount of ice formed on the insulator strings and bridged the space between the insulator units, resulting in flashover occurring. Investigation of the March 10, 1986 events suggested that it would be difficult to explain the flashovers in terms of ice bridging of line insulators because the amount of freezing rain which had preceded the events was quite small, in the order of 7 mm (Gorski, 1986). The results of a previous study (Farzaneh and Melo, 1990) indicated that a film of water on the surface of the ice, accreted on a short string of insulators from fog water, had a very high conductivity at the beginning of the de-icing period, i.e. when the ambient temperature was increased after the ice accretion period. It was also shown that the duration of the high-conductivity water film on the surface of the accreted ice increased with a decrease in the rate of temperature increase. Although the results obtained in that work indicated that the fog water accretion on insulators could reduce the withstand ability of insulators, additional studies were needed to relate these results to the flashover problems occurring on March 10, 1986 on Ontario Hydro's 500-kV line or/and station insulators. In order to gain a better understanding of the mechanisms of the observed flashovers and to clarify the role of fog accretion, this paper investigates ac leakage current as well as minimum flashover voltage of insulators, partially iced by fog during de-icing periods at various rates of increase in temperature.

EXPERIMENTAL CONDITIONS AND PROCEDURES

Experiments were performed in a 4.8-m x 2.8-m x 3.8-m cold room where a minimum temperature of –35° ± 1° C could be obtained (Fig. 1). A short string of 3 or 4 clean and dry porcelain insulator units was installed vertically at the center of the cold room and then energized by a constant voltage of 14 $kV_{r.m.s.}$ per unit. This level of voltage is the same as the operating line-to-ground voltage ratio for the strings on Ontario Hydro's 500 kV system. High voltage was supplied through a 120 kV, 125 kVA transformer; the primary of the transformer was connected to a

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KEY WORDS: Iced-insulators, rime fog, flashover.