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Icing Event Occurrence in Québec: Statistical Analysis of Field Data

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ABSTRACT

Statistical analysis of data coming from about 170 icing test sites in Québec was performed in order to establish the parameters of the following distributions: Annual Number of Icing Event Recurrence (N_e), Ice Residency Period (t_{rp}), and Total Annual Ice Residency Period (t_{ia}). These distributions are necessary for modeling the wind speed associated with icing events and for determining the combined wind-on-ice loads on overhead transmission lines. The studied empirical data records for N_e were approximated with the negative binomial discrete distribution, and t_{rp} by Weibull 2-parameter distribution. The statistical parameters for t_{ia}, representative for the whole territory of the Province of Québec were found to be 144 h (6 days) with one-sided 95% confidence limit of 432 h (18 days). These values could be considered the best estimators of the return period for the reduced wind speed associated with icing events for data-based predicting of combined wind-on-ice loads.

INTRODUCTION

The combined wind-on-ice loads are one of the most important, frequently critical, factors to consider in overhead transmission line design. A review of the literature shows a continuously increasing need for sufficient and reliable statistical data for improving the prognosis of these loads (ASCE, 1991; IEC, 1991; Ghannoum, 1993). Given the small probability of simultaneous occurrence of mutually independent meteorological phenomena, such as extreme icing and extreme wind, the design standards and guidelines for overhead transmission lines recommend combining extreme icing with a reduced wind speed associated with icing events, V_{ice}. For instance, ASCE (1991) recommends to estimate the expected value of the maximum wind speed during a 7-day ice residency period. IEC (1991) recommends combining extreme icing with the maximum wind speed recorded during a 72-h icing event period. Goodwin (1982) proposes combining annual extreme ice with daily extreme wind speed measured during and immediately following ice events. Krishnasami and Kulendran (1996) proposed that, in Ontario, a reduction factor for V_{ice} between 0.45 and 0.75 be used in wind-on-ice load calculations. The authors underline, in accordance with IEC and ASCE, that the best way of establishing reliable values of this factor is undoubtedly the statistical approach. In Québec, V_{ice} is specified as 0.7 to 0.8 of the maximum wind speed combined with a reduced icing (Ghannoum, 1993).

Savadjiev et al. (1998, 2000) showed that the return period for wind speed associated with icing events can be specified correctly only on the basis of statistical analysis of field data for the annual recurrence and persistence of icing events. Indeed, the longer the residency period of icing buildup on transmission line equipment, the greater the probability of strong wind acting simultaneously. Thus arises the necessity of studying the probability distribution of the t_{ia}, valid for the whole territory of Québec where overhead transmission lines are built.

A source of such statistical information has existed in Québec since 1974, when Hydro-Québec established a network with over 170 Passive Ice Meters (PIM) throughout the province, within a grid dimension of about 50 km. The PIM, sketched on Fig. 1, is a simple, robust and useful instrument, designed mainly for measuring precipitation icing accumulation. Usually, it is placed 1.2 m above ground, and its metallic receiving cylinders are oriented N-S and E-W. The detailed description of the PIM performance and technical characteristics, as well as the usefulness of the recorded data for transmission line design, are beyond the scope of this paper, and the reader may refer to Laflamme and Périard (1996) and Elfashny et al. (1996).

Recently, statistical analysis of data for icing event recurrence and ice residency period was made by Elfashny et al. (1996), where the data from each PIM station were processed separately. Although useful for telecommunication towers, this statistical analysis cannot be applied to transmission lines built over a long distance, and to the unification of design standard criteria.

There is a very large number of publications on the hazard of ice accretion in Canada or in Québec (for example, see McKay and Thompson, 1969). Most of these papers concern the hazard of the icing process - freezing rain, in-cloud icing or wet snow, and not the hazard of recurrence and persistence of the ice buildup itself. Usually, the published data and information are very general and cannot be used for further analysis.

Using the data provided by PIM since 1974, the main purpose of the present study is the statistics-based determination of the return period of the design wind speed associated with icing events. The results obtained are fundamental for predicting the combined wind-on-ice loads on transmission line conductors.

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KEY WORDS: Atmospheric icing, statistical analysis, ice event recurrence, ice residency period.