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Predicting Extreme Loads on a Power Line from Freezing Rainstorms

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ABSTRACT

Several prediction models are checked against experimental freezing rain simulations and field observations. Goodwin's model is used to estimate ice loads occurring in Winnipeg, Canada, from the available 126 years of weather data. Emphasis is put on predicting extreme ice loads from this historical record. A Monte Carlo simulation is proposed to address the random variations of ice storms. The simulation suggests that the current practice of using a return period-based, extreme ice load as the design ice load is unsafe unless the return period is substantially longer than a power line's lifetime. A probability-based approach is suggested as a better alternative.

INTRODUCTION

Freezing rainstorms are not unusual at extreme latitudes. Once a freezing rainstorm occurs, substantial ice can be deposited on an overhead power line that may result in a broken line and toppled towers. One recent example was the 1998 Great Ice Storm in Eastern Canada in which damage to power systems has been estimated at about C$2 billion. Obviously, it is important to reliably estimate the extreme ice load.

An extreme ice load is found most often from local historical weather data. However, an icing model is needed to estimate the ice load from the known weather conditions. Many icing models are available. See, for example, Chaine and Castonguay (1974), Goodwin et al. (1982), Lozowski et al. (1983), Makkonen (1984, 1996), Poots and Skelton (1991a, 1991b), as well as the overview given in Poots (1996). Extensive freezing rain experiments on short, unheated, fixed conductor samples have been performed recently at the University of Manitoba. They confirm, for the first time, that Goodwin's simple icing model surprisingly holds for the weight of both dry and wet ice growths as well as for wind-on and wind-off cases (Lu et al., 1998a). An updated summary of these experiments will be given in this paper and a comparison will be made with field observations.

One fundamental issue in analyzing ice storms is how to predict the effect of ice storms from historical records. It is a common design practice to use an extreme ice load whose return period equals a line's planned lifetime (CSA, 1987; ASCE, 1991). Therefore, predicting an extreme load is simplified to identifying the probability distribution of an extreme ice load so that the extreme value corresponding to a given return period can be found. Another fundamental issue is how reliably an extreme ice load distribution can be identified. A Monte Carlo simulation is used in this paper to examine both these issues. Then a probability-based procedure is proposed to find a design-oriented, extreme ice load. In addition, it will be demonstrated that a "true" extreme ice load distribution, which governs the randomness of the annual maximum ice thickness, is inherently difficult to identify because a historical record is merely one possible realization from the viewpoint of stochastic theory.

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KEY WORDS: Overhead line, freezing rainstorm, ice load, Monte Carlo simulation.

ESTIMATING AN EQUIVALENT RADIAL ICE THICKNESS

It is a common practice to use an equivalent radial ice thickness (ice thickness, b, for short) to represent the ice load. The advantage is that the ice thickness, unlike the ice load, is relatively independent of a conductor's diameter (Lu et al., 1998a).

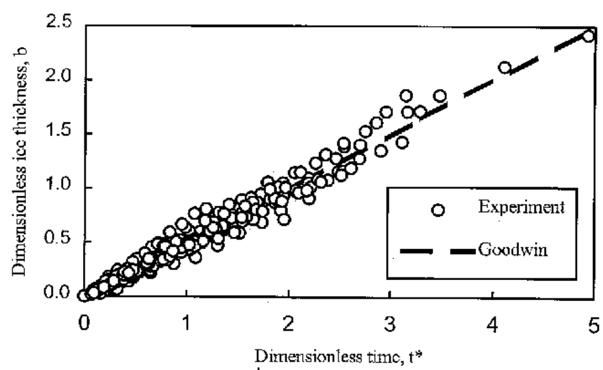

Fig. 1 Comparison of Goodwin's predictions with data from freezing rain simulations for unheated conductor samples

Factor	Field range	Expt. range
Air temperature (°C)	0 ~ –10	–1 ~ –25
Precipitation rate (cm/hr)	0.0 ~ 0.5	0.3 ~ 1.9
Total precipitation (cm)	0 ~ 4	0.5 ~ 5.9
Side wind speed (m/s)	0 ~ 15	0 ~ 10
Droplet's mvd † (mm)	0.5 ~ 1.5	0.8 ~ 1.4
Conductor radius (cm)	0.2 ~ 2.5	0.6 ~ 2.2

† : Median volume diameter (mvd)

Table 1 Comparison of field observations and simulated ranges for individual factors