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Characterization of Ice and Concurrent Wind for Loading of Transmission Line Structures in Iran

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ABSTRACT: In this paper, the parameters required for the ice and concurrent wind loading case, including the radial equivalent ice thickness and the concurrent wind speed for the return periods in the structures of the power transmission lines, are determined according to the standard criteria of IEC 60826. Loading parameters have been calculated using two-variable hazard curves and compared with simplified methods in IEC 60826. Ice and concurrent wind hazard curves are prepared using data recorded in 15 selected meteorological stations in the cold regions of the country (including heavy and ultra- heavy areas according to the climate-zoning map of the transmission lines). Numerical simulations (CRREL model for Freezing Rain and Cylindrical Growth of Wet Snow Sleeves model for Wet Snow) have been used to determine the thickness of ice formed around the conductor of the transmission lines due to the lack of direct data from the measurement. The results show significant conservatism of the reduction factors of the ice and concurrent wind in IEC 60826 standards at most of the studied meteorological stations. Accordingly, using the ice and wind hazard curves at the stations, the reduction factors are determined and presented to calculate the values of loading parameters in ice and wind loading case in terms of their reference values (which are available in the zoning maps). The proposed reduction factors are consistent with the standards of IEC 60826 and are suitable for use in loading and designing the structures of transmission lines with different return periods in the cold regions of the country.

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1. INTRODUCTION

One of the most important loading cases in power transmission lines is the simultaneous combination of ice and wind, which creates significant horizontal forces on conductors, towers and other structural components of transmission lines. Standards for the design of power lines such as IEC 60826 [1] specify the need to determine the parameters of ice and concurrent wind loading for corresponding to the specified return period. Ice and wind loading parameters include the thickness (or weight) of ice formed around the conductor wire and the wind velocity coinciding with the ice. In the current standard for loading of transmission lines in Iran, [2] the values of the loading parameters in the ice and wind load case are not provided based on the probabilistic approach. Due to the lack of studies in this field in the country, determination of the values of ice and concurrent wind loading parameters with specified return periods, in accordance with the weather conditions of the country is of great importance.

Numerous research activities have been carried out around the world to determine the parameters of ice and Concurrent wind loading on power transmission lines using numerical meteorological models as well as the development of probabilistic models using the resulting data [3-6].

In this paper, the parameters of ice and concurrent wind loading case including equivalent radial ice thickness and Concurrent wind speed for specified return periods are determined. For this purpose, Bivariate Hazard Curve approach was used and the loading parameters were determined according to main criterion of IEC 60826 standard. Ice and wind bivariate hazard curves were compiled using data recorded at 15 selected meteorological stations in the cold regions of the country. In addition, using the hazard curves, the values of the reduction factors are presented to determine the values of the parameters of loading in the ice and Concurrent wind cases, using the reference values of the parameters (which are included in the zoning maps).

2. METHODOLOGY

The general process of producing ice and Concurrent wind hazard curves for a typical meteorological station is presented in “Fig. 1”. Using statistical analysis of the hazard curves obtained at all selected stations, reduction factors are presented in accordance with IEC 60826 criteria for use in cold regions of the country, which can be used for calculate the ice and Concurrent wind loading cases. Extreme value distribution of the type-I (Gamble) was used to the extreme

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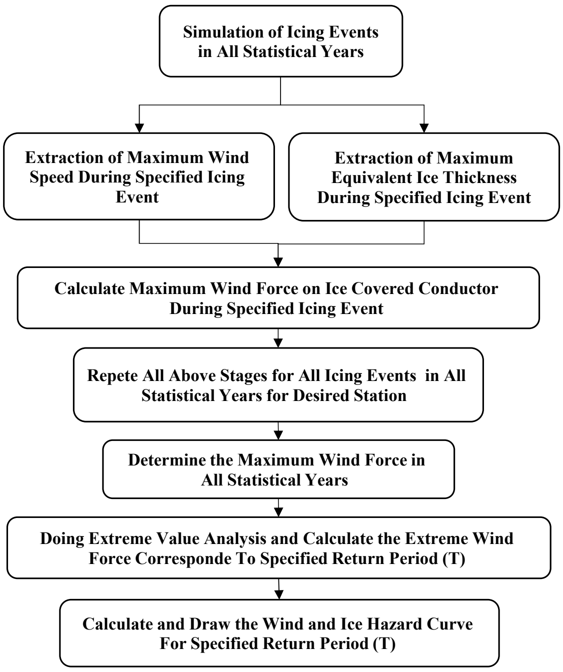

Fig. 1. Process of preparing ice and wind hazard curves for a typical meteorological station

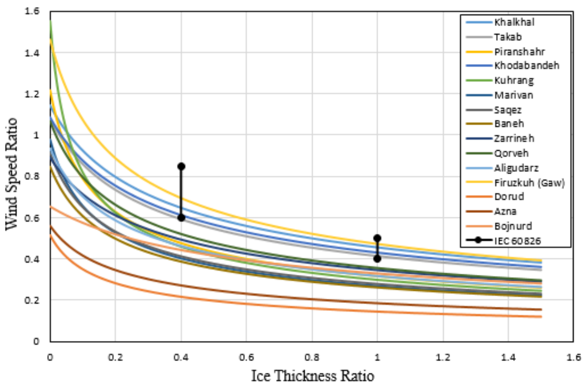

Fig. 2. Normalized ice and wind hazard curves to reference values for all stations (T=50 years)

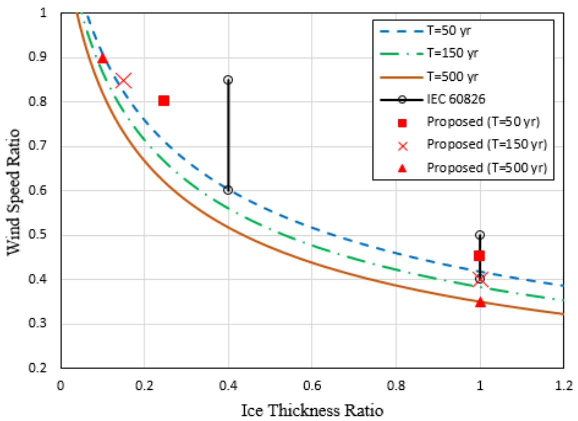

Fig. 3. Proposed reduction factors compared to 84% hazard curves and IEC 60826 factors

value analysis on the maximum annual values of wind force applied to the ice-covered conductor.

Due to the lack of direct measurement of atmospheric icing properties in meteorological stations, the equivalent radial thickness of ice required in this study was determined using numerical simulation based on ice accretion models. The simulation of atmospheric ice accretion event and determination of its characteristic parameters is performed using the simplified CRREL model for freezing rain [7] and the Cylindrical Growth of Wet Snow Sleeves model [4] for wet snow. In this study, the 15 meteorological stations were selected in the first place with sufficient data record (at least 30 years) and secondly with relatively severe ice and wind conditions (located in the cold and windy regions of the country).

3. RESULTS AND DISCUSSION

The hazard curves for the 15 meteorological stations (normalized to the reference values for all stations), have been shown in "Fig. 2" for the 50-year return period. The normalized hazard curves to the reference values are, conceptually, the reduction factors of the combined ice and wind loading cases provided in IEC 60826. The values of the above factors include two linear zones in the hazard curves corresponding to the two standard IEC load cases. The two zones are shown as black lines in "Fig. 2". The hazard curves in "Fig. 2" at most stations are lower than the IEC reduction factors, and therefore, the IEC factors at most stations are conservative.

The average plus one standard deviation of hazard curves (84% curve) for all the stations have been shown in "Fig. 3". The range of IEC 60826 reduction factors for ice and wind load cases is also illustrated in this Fig.. Using the hazard curves in "Fig. 3", the reduction factors are calculated for the stations under study, and their mean values plus a standard deviation are presented as the desired factors for ice and wind loading and are shown in "Fig. 3".

Proposed values of reduction factors for combined ice and wind loading cases in the cold regions of the country are also presented in "Table 1". The corresponding factors presented in IEC 60826 are also presented in this table for comparison. As shown in the table, the values of the B1 and B2 at different return periods are close to the upper and lower bounds of the IEC coefficients, respectively. The values of B3 in the different return periods are relatively significant (35 to 75%) lower than the IEC coefficient. Therefore, the proposed reduction factors are less conservative than the IEC coefficients and better fit the regional hazard curves.

4. CONCLUSIONS

In this paper, the parameters required (reduction factors) for loading case of ice and concurrent wind for transmission lines are presented according to IEC 60826 standard concepts. For this purpose, bivariate ice and wind hazard curves were prepared using data recorded at 15 selected meteorological stations and simulation of the assertion of icing events. The reduction factors are set for different return periods and for cold regions of the country. Using these factors and reference values of ice thickness and wind speed (available in zoning maps), the values of

Table 1. Proposed values of reduction factors for combined wind and ice loading of transmission lines in cold regions of the country

Reduction Factors of IEC 60826	Return Period (year)			\Reduction Factor
	50	150	500	
0.6~0.85	0.80	0.85	0.90	B_1
0.4~0.5	0.45	0.40	0.35	B_2
0.4	0.25	0.15	0.10	B_3

the ice and concurrent wind loading parameters can be calculated. Proposed factors are less conservative than the corresponding values in IEC 60826 and are better adapted to climate conditions in the country.

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