Analysis of Snow and Wind-on-Snow Loads in Southern Alberta

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Abstract— **Experience with the transmission system in Southern Alberta has shown that snow and wind on snow loads should be considered in the design of transmission and distribution lines. AltaLink, Ltd is proposing to build a new 500 kV line between Edmonton and Calgary. A snow accretion model was used to estimate snow loads in the area. Using historical weather data, each snow storm was analyzed using the Snow Accretion Model discussed in a companion paper which gives the estimated shape, mass and wind load. The model results were compared with records of outages on the transmission system. Extreme value analyses of the model results were performed and compared for the Gumbel distribution, the generalized extreme value distribution and peaks-over-threshold values in a generalized Pareto distribution.**

I. Introduction

AltaLink, Ltd proposes to build a new 500 kV line between Edmonton and Calgary, Alberta on the high plains east of the Canadian Rocky Mountains. The transmission system in the area has had outages due to both snow accretion on the wires and in-cloud icing. Glaze ice due to freezing rain is relatively rare and has not significantly affected the system in the past. In this paper, the analysis of structural loads due to snow accretion is described.

The modeling and analysis includes the choice of weather stations and the period of record to be used, extracting the storms and running the model, normalizing the results and performing extreme value analyses.

II. WEATHER DATA

The model uses the station latitude, longitude and elevation, the hourly wind direction and speed, the peak gust wind direction and speed, the temperature, atmospheric pressure, relative humidity, precipitation (water equivalent), visibility and present weather code. Only stations in the area of the proposed line that regularly observed and recorded all of this data were used. Fig. 1 shows the weather station locations.

The data for each station was examined to find gaps in coverage and missing individual parameters. A gap occurs when there is no data recorded for an hour. Sometimes, a single instrument is out of service and the parameter measured by that instrument is missing. The total hours in the year were compared with total missing hours, the missing hours for each parameter of interest and the hours missing in each month. Table I shows an excerpt from a summary of missing data.

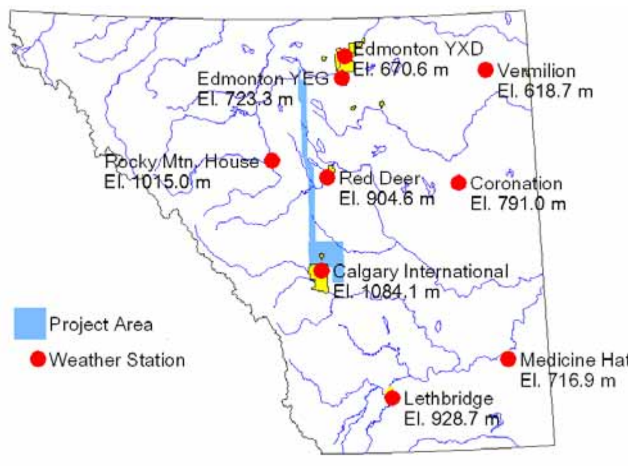


Fig.1 Weather Stations

TABLE I
EXAMPLES OF NUMBER OF HOURS WITH MISSING DATA

Year	Total Hours in Year	Calgary	Coronation	Edmonton International Airport	Edmonton City Center	Lethbridge
1953	8,760	-	196		1	3
1954	8,760	7	1,041		-	9
1955	8,760	-	22		1	-
1956	8,784	1	11		2	-
1957	8,760	-	-		-	7
1958	8,760	-	-		-	6
1959	8,760	-	-		-	11
1960	8,784	-	2	Start	-	-
1961	8,760	-	-	-	-	-
1962	8,760	-	9	23	5	-
1963	8,760	-	-	-	-	-
1964	8,784	-	-	-	-	-
1965	8,760	-	-	8	-	844

Each gap and missing hour was reviewed. In some cases the gaps and missing data were all in the summer months allowing that year to be used. Some stations, for example, Calgary, had practically no data missing, others, for example, Coronation in 1953 and 1954, had so much data missing that those years could not be used. In most cases only single hours were missing data, which were interpolated for that hour. At some stations, the height of the anemometer changed during the time period used in the model. In that case, the wind speeds were all corrected to a common height of 10 m. The wind direction was artificially set to always be perpendicular to the wires.

III. MODELING

The snow was modeled for a 40 mm diameter conductor with a 400 m span at a height above ground of 10 m. To evaluate the influence of wire diameter and height above ground, a 12.7 mm (½ in) shield wire was modeled at heights of 10, 20, 30 and 40 m at one station, Red Deer. For each storm, the model output includes the maximum unit mass, the maximum unit transverse load due to the hourly wind and the maximum unit transverse load due to the gust wind. The density of the snow accretion depends on the wind speed and the liquid water content during the storm. Figure 2 shows histograms of the snow densities for the storms with maximum snow mass and for the storms with maximum gust wind load (2 year epochs). The storms with the largest wind-on-snow loads were not always the storms with the heaviest snow accretion. Due to the wide range of snow densities, snow and wind-on-snow loads were also normalized to the glaze ice equivalent ice thickness and wind-on-ice load.

IV. EXTREME VALUE ANALYSIS

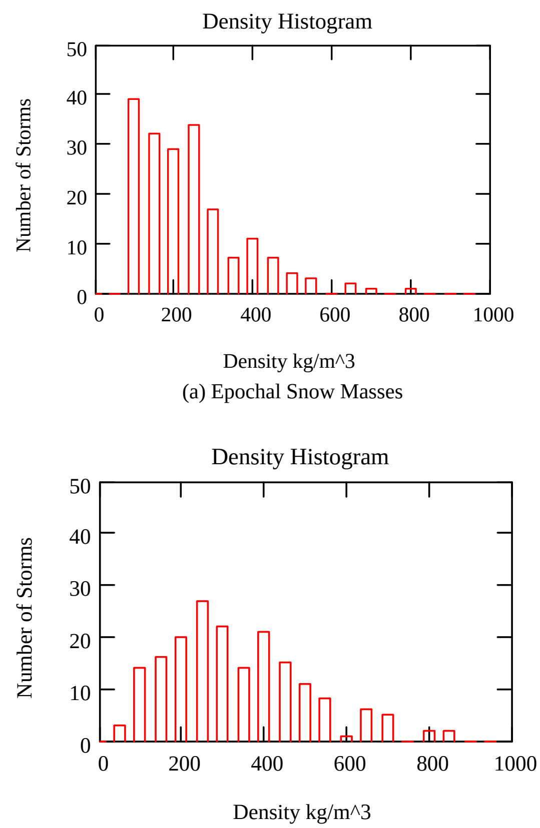
Three extreme value distributions were used to analyze the data: the Gumbel and generalized extreme value (GEV) using epochal maxima, and the generalized Pareto distribution using values exceeding a threshold. The Gumbel distribution (also called the Fischer-Tippet Type 1) has been the most commonly used of the extreme value distributions to evaluate environmental variables.

A. Gumbel Distribution

The method of moments [1] was used to fit the Gumbel Distribution [2]. The analysis was done using epochs of 2 years. For graphing the data, the epochal maxima are plotted vs. the unbiased plotting position described by Gringorten [3]. Ninety-five percent confidence intervals were calculated after Lowery and Nash [1].

B. Epochal maxima with Generalized Extreme Value Distribution (GEV)

Two year epochs were used for the GEV Distribution which is described in Nash [4]. The probability weighted moments method, also known as L-moments [5] was used to determine the GEV distribution parameters



(a) Epochal Snow Masses

(b) Epochal Gust Wind Loads

Fig. 2 Comparison of Snow Densities

C. Peaks-Over –Threshold values and Generalized Pareto Distribution

Storms in which snow accretes on the wires may occur infrequently. When using the epochal methods, some epochs have no significant snow loads, while in others there is more than one severe storm, each of which may cause larger snow loads than the most severe storms in milder epochs. Thus, the epochal methods may not include large, but not worst-of-the-epoch, snow loads in the estimation of the parameters of the extreme value distribution. The peaks-over-threshold (POT) method has the advantage of using all of the storms with the parameter of interest exceeding a specified value regardless of the epoch in which the storm falls. In this study, the threshold load was chosen so that the occurrence rate of the extremes was approximately one per year. The method of probability weighted moments [6-8] was used to determine the parameters for the Generalized Pareto Distribution (GPD) as described in Wang [8].

D. RESULTS

The extreme value analyses yielded four parameters: unit mass, equivalent radial glaze ice thickness, unit hourly wind on snow load and unit gust wind on snow load. Figures 3 and 4 show typical plots of the results for the Gumbel, GEV and GPD Distributions.

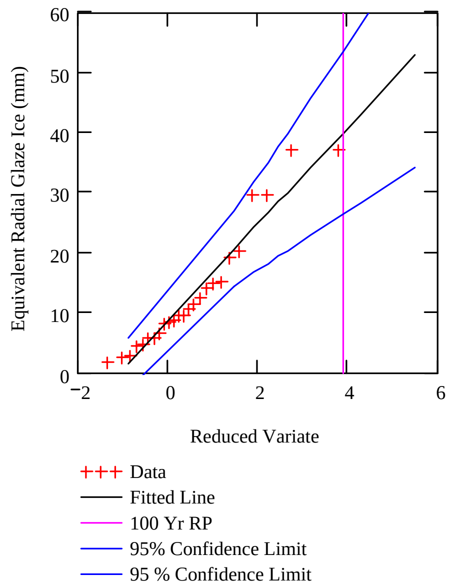
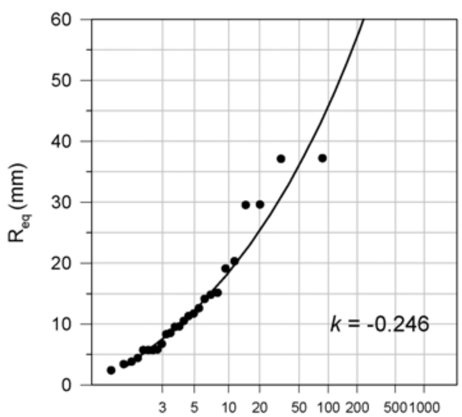
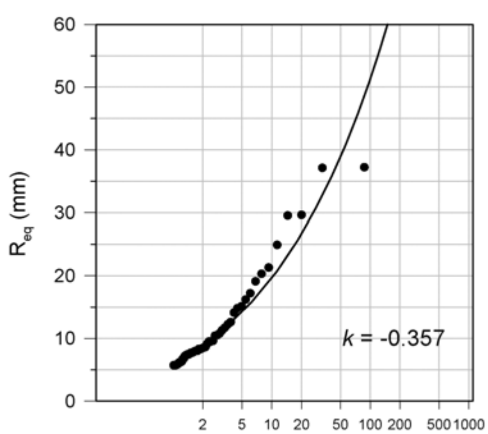


Fig. 3 Equivalent Glaze Ice Thickness at Red Deer
Gumbel Distribution



(a) GEV



(b) GPD

Fig. 4 Equivalent Glaze Ice Thickness at Red Deer
GEV and GPD Distributions

The analysis at Red Deer also showed that, in general, the snow thickness decreases slightly with height with the wind speeds increasing. The snow thickness is slightly less for the shield wire than for the conductor while the wind speeds are essentially the same. The variation of wind speed with height approximates the power law relationship used to adjust the wind speed data to a common height.

In order to keep the physical significance of snow loads, the snow and wind-on-snow loads were normalized to thicknesses based on a snow density of 350 kg/m^3. The wind-on-snow loads were then normalized to wind speeds based on that thickness. Table II shows the snow thicknesses for a 100 year mean recurrence interval with Table III showing the wind speeds.

TABLE II
SNOW THICKNESS (MM) WITH DENSITY 350 KG/M^3
100 YR MEAN RECURRENCE INTERVAL

Station	Gumbel	GEV	GPD
Calgary International A	71	81	85
Coronation A	40	66	76
Edmonton City Center A YXD	54	59	62
Edmonton International A YEG	43	50	50
Lethbridge A	105	116	133
Medicine Hat A	51	53	58
Red Deer A	73	82	92
Rocky Mountain House	70	73	73
Vermilion	62	68	76

TABLE III
WIND SPEEDS ON SNOW THICKNESS IN TABLE II (KM/HR)
100 YR MEAN RECURRENCE INTERVAL

	Hourly Wind Speeds			Gust Wind Speeds		
Station	Gmbl	GEV	GPD	Gmbl	GEV	GPD
Calgary Internationa l	45	45	44	67	64	68
Coronation	51	42	39	65	57	54
Edmonton City Center	37	34	34	61	58	60
Edmonton Internationa l	42	40	40	64	59	64
Lethbridge	43	43	40	79	80	75
Medicine Hat	46	46	40	61	59	60
Red Deer	44	40	37	70	69	63
Rocky Mtn. House	44	43	44	44	43	44
Vermilion	41	42	40	44	45	46

Both the hourly and gust wind speeds are close to the same for all three distributions. The normalized snow thickness is generally lowest for the Gumbel distribution and highest for the GPD Distribution. AltaLink chose a single representative snow thickness for design. The line is being designed for 70 mm radial snow with a density of 350 kg/m^3. The concurrent wind pressure is 310 Pa for single circuit structures and 330 Pa for double circuit structures which correspond to wind speeds of 81 and 84 km/hr, respectively. The wind speeds were adjusted from the 10 m model height to heights of 30 m for the single circuit towers and 40 m for the double circuit towers.

V. ACKNOWLEDGEMENTS

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