Attachment N3-TH-16d

Details of the Power Systems Engineering Construction Standards Variable

PSE developed a construction standards variable for distribution for an Ontario utility.

The **construction standards index (or loading)** variable measures the minimum requirements for strength of distribution structures, which vary by geographic region. Distribution lines constructed in different regions must withstand different combinations of ice and wind due to local weather. A line designed for harsher loading conditions is more expensive to construct because it may require higher class poles, greater set depth, specialized insulators, and/or stronger hardware.

The loading variable is a way to quantify the expense associated with distribution line construction based on local weather conditions and the resultant regulatory requirements. This is accomplished by evaluating the percentage of strength capacity utilized under required load cases for a base distribution structure in different regions. We would expect that a higher minimum construction requirement for a utility would result in higher total costs.

Per the Canadian Standards Association (CSA) and the National Electrical Safety Code (NESC), overhead distribution lines constructed throughout Canada and the United States must withstand a minimum combination of accumulated ice and wind based on local extreme historical weather conditions. As a result, the required minimum design/build structural strength for an overhead distribution line is dependent on the physical location of the line.

This minimum structural strength requirement has a direct influence on the overall capital cost a utility must devote to its overhead distribution plant. For example, a distribution structure designed for harsher loading conditions is more expensive to construct because it may require larger diameter poles, greater setting or foundation depth, specialized insulators, and/or stronger hardware.

Furthermore, since these minimum strength requirements are developed from documented historical weather conditions, they provide an indirect indication of the severity of extreme ice and wind storms that overhead distribution lines are exposed to, which can influence operational and maintenance costs.

To account for the influence of CSA and NESC minimum overhead distribution line structure strength requirements and associated extreme weather conditions as they relate to total cost benchmarking, Power System Engineering's distribution line design engineers developed a related variable for statistical analysis. This was accomplished by evaluating the percentage of utilized strength capacity, under required CSA and NESC load cases, for a base distribution structure in different zones.

"Percentage of utilized strength capacity" is the percentage of the load resulting from specific design criteria (e.g., this line was designed to meet winds of X mph and ice of Y thickness) as a function of the overall maximum strength of the structure. The variable is a way to quantify the expense associated with distribution line construction based on local weather conditions. There were three main steps in developing the variable, as described below.

Development of Variable

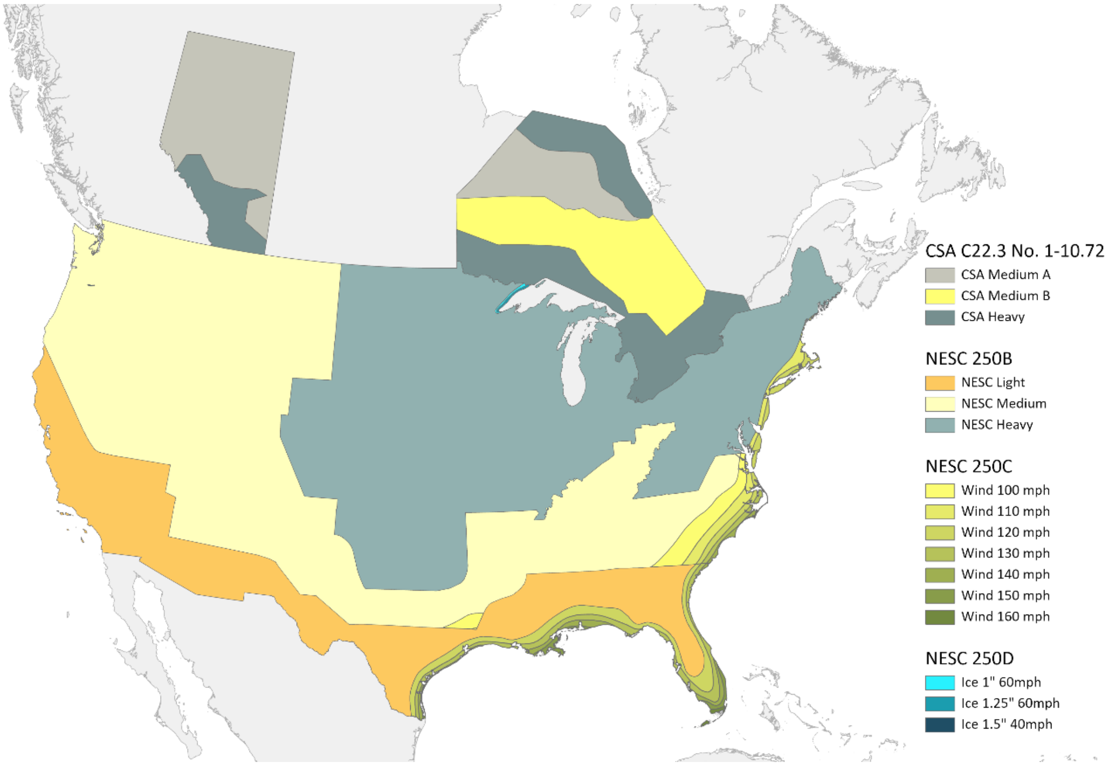
1. Zones specified by the CSA and NESC were mapped and overlaid with utility service territories.

Industry standards in Canada and the United States dictate minimum requirements for strength of distribution structures, which vary by geographic zone. During design, ice and wind loads are applied to a structure model to analyze strength in terms of percentage of strength capacity used. The zone boundaries and the required ice and wind load cases are outlined in the Canadian Standards Association

(CSA) Overhead Systems Standard C22.3 No. 1-10 for Canada, and the National Electrical Safety Code (NESC) for the United States. The loading zones are illustrated in Figure 1 below.

Utility service territories were overlaid with the above loading zone map. GIS analysis revealed the percentage of a given utility's service territory that fell into each loading zone.

Figure 1



2. Loading capacity was evaluated for a base structure in each zone.

A base distribution structure was identified to represent a typical application throughout the industry. Specifications are outlined in Table 1. Although this structure cannot represent an exact base structure for every utility, it is reasonable for side-by-side comparison of relative structure loading values for utilities in each zone.

Table 1

Base Distribution Structure Specifications

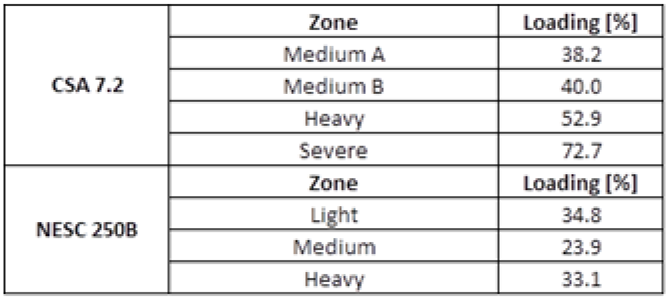
	Metric		English	
Pole Material	Wood - Douglas Fir			
Pole Length	13.72	m	45	ft
Pole Class	3			
Span Length	45.72	m	150	ft
Framing	RUS - C1.11			
Voltage	15 kV			
Construction Grade	CSA Grade 2 / NESC Grade C			
Distribution Conductor	336 (18/1) ACSR			
Neutral Conductor	336 (18/1) ACSR			
Design Tension @ NESC Heavy	11.74	kN	2640	lb

Table 2 represents the loads as a percentage of the maximum allowable for the base distribution structure. For example, the design criteria for CSA 7.2 zone “Medium A” is 38.2% of the maximum load strength of the base structure. The design criteria required for a structure in CSA 7.2 zone “Severe” is 72.7% of the maximum load strength of the base structure described in Table 1.

Industry best practice is to consider local historical weather data for distribution line designs, but the deterministic load cases defined by the CSA and NESC provide minimum requirements for each zone. Therefore, the load cases identified in CSA C22.3 No. 1-20 7.2 and NESC Rule 250B were used for analysis. It is noted that NESC Rules 250C and 250D are not applicable to structures and supported facilities shorter than 18 meters (60 feet) above ground or water level, and the base structure described in Table 1 does not meet this criteria. Loading zones with the same names in Canada and the United States are not equivalent, e.g. the CSA “Heavy” zone specifies different accumulated ice and wind loads than the NESC “Heavy” zone. Multipliers, including strength factors for structure components and load factors for ice and wind loads, are also specified in each code and were included in this analysis. PLS-CADD Lite, an engineering modeling software application for distribution and transmission structures, was used to complete nonlinear analysis of the base structure for each zonal load case.

Table 2

Loading Capacity Usage Percentages by Loading Zone



CSA 7.2	Zone	Loading [%]
	Medium A	38.2
	Medium B	40.0
	Heavy	52.9
	Severe	72.7
NESC 250B	Zone	Loading [%]
	Light	34.8
	Medium	23.9
	Heavy	33.1

3. **Loading values were calculated for each utility based on the area and loading percentages.**

The area percentages derived from the zone map and utility service territory map were multiplied by loading value percentages from PLS-CADD analysis for each loading zone present in a given utility service territory. These values were summed to produce an overall loading value for each utility. This overall loading value represents (roughly) the minimum design/build structural strength required for the utility’s service territory.

Data Sources

1. United States load cases: National Electrical Safety Code (NESC) Rules 250B, 250C, and 250D
2. Canadian load cases: Canadian Standards Association (CSA) Overhead Systems C22.3 No. 1-10 7.2
3. Nonlinear loading models: PLS-CADD Lite Version 17.50
4. GIS mapping software: ArcGIS Pro v2.1, ArcGIS Server 10.5, SQL Server 2014
5. Utility service territories: S&P Global – Platts and Power System Engineering acquired service territories <https://www.platts.com/maps-geospatial>

PLS-CADD Lite Model Inputs

Zonal weather criteria are defined in NESC 250B and CSA 22.3 No. 1-10 7.2 and summarized in Table 3 below. The NESC set includes two additional sets of load cases which do not have counterparts in the CSA. These are Rule 250C: extreme wind loading and Rule 250D: extreme ice with concurrent wind loading. Separate zones were identified for these rules as well.

Table 3

Weather Criteria

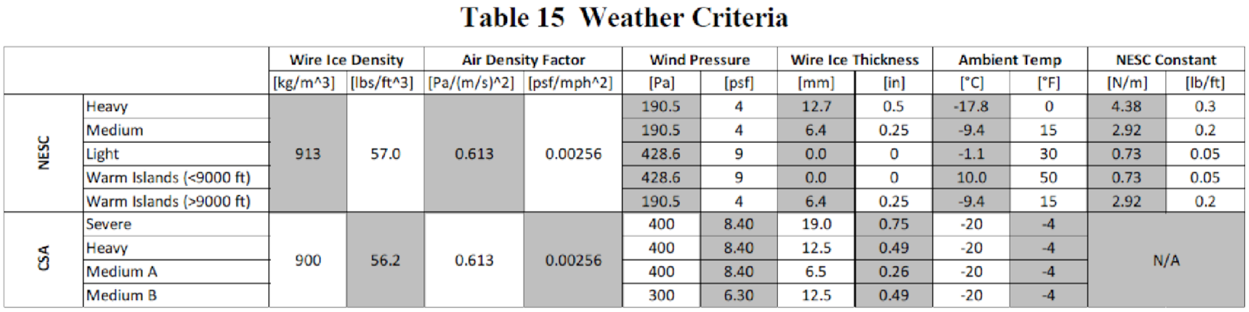


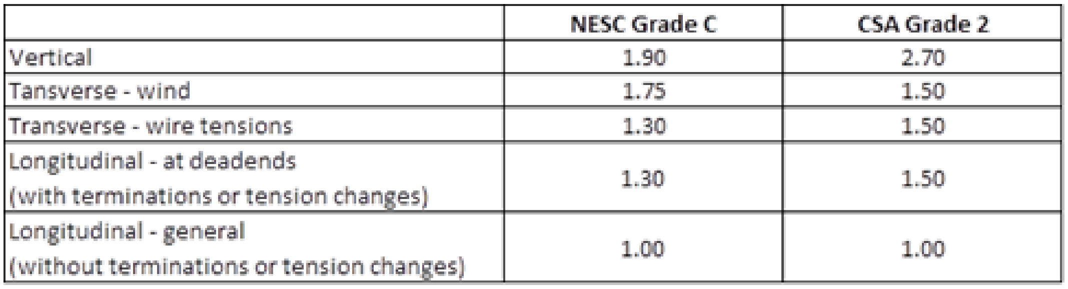
Table 15 Weather Criteria

		Wire Ice Density		Air Density Factor		Wind Pressure		Wire Ice Thickness		Ambient Temp		NESC Constant	
		[kg/m^3]	[lbs/ft^3]	[Pa/(m/s)^2]	[psf/mph^2]	[Pa]	[psf]	[mm]	[in]	[°C]	[°F]	[N/m]	[lb/ft]
NESC	Heavy	913	57.0	0.613	0.00256	190.5	4	12.7	0.5	-17.8	0	4.38	0.3
	Medium					190.5	4	6.4	0.25	-9.4	15	2.92	0.2
	Light					428.6	9	0.0	0	-1.1	30	0.73	0.05
	Warm Islands (<9000 ft)					428.6	9	0.0	0	10.0	50	0.73	0.05
	Warm Islands (>9000 ft)					190.5	4	6.4	0.25	-9.4	15	2.92	0.2
CSA	Severe	900	56.2	0.613	0.00256	400	8.40	19.0	0.75	-20	-4	N/A	
	Heavy					400	8.40	12.5	0.49	-20	-4		
	Medium A					400	8.40	6.5	0.26	-20	-4		
	Medium B					300	6.30	12.5	0.49	-20	-4		

Load factors and strength factors are summarized in Tables 4 and 5, respectively.

Table 4

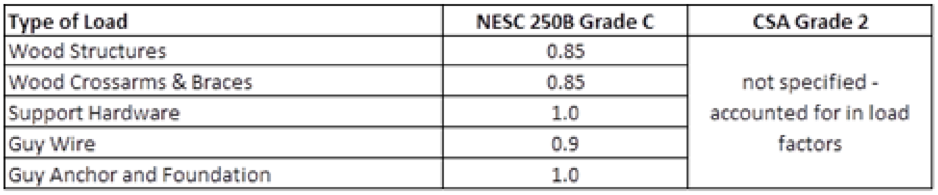
Load Factors



	NESC Grade C	CSA Grade 2
Vertical	1.90	2.70
Tansverse - wind	1.75	1.50
Transverse - wire tensions	1.30	1.50
Longitudinal - at deadends (with terminations or tension changes)	1.30	1.50
Longitudinal - general (without terminations or tension changes)	1.00	1.00

Table 5

Strength Factors



Type of Load	NESC 250B Grade C	CSA Grade 2
Wood Structures	0.85	not specified - accounted for in load factors
Wood Crossarms & Braces	0.85	
Support Hardware	1.0	
Guy Wire	0.9	
Guy Anchor and Foundation	1.0	