Ontario Energy Board

Commission de l'énergie de l'Ontario

ONTARIO ENERGY BOARD

Appendix A

Minimum Design Criteria
for the Reference Option of the E-W Tie Line
(230kV Wawa to Thunder Bay Transmission Line)

November 9, 2011

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1. CODES, STANDARDS AND DOCUMENTS REFERENCED IN THIS APPENDIX			
	DOCUMENT	**DATE**	**REVISION**
Design Codes:	CSA C22.3 No.1-06 "Overhead Systems"	Jul-07	06
	CSA C22.3 No. 60286 “Design Criteria of Overhead Transmission Lines”	2006	
Documents:	Ontario Energy Board “Transmission System Code”	Jun 10-10	N/A
	Ontario Energy Board “Minimum Technical Requirements for the Reference Option of the East-West Tie”	Aug 12-11	R4.0
	Ontario Power Authority “Long Term Electricity Outlook for the Northwest and Context for the East-West Tie Expansion”		
	Independent Electricity System Operator “Feasibility Study: An assessment of the westward transfer capability of various options for reinforcing the East-West Tie”		
Reference Documents:	ASCE 74, “Guidelines for Electrical Transmission Line Structural Loading”	2010	3rd Edition

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2. CONDUCTOR DATA			
Type	**ACSR or ACSR Trapezoidal Stranded**		
Application	230 kV Overhead Phase Conductor		
N: number of subconductors	To be determined by Proponent		
Condition for Maximum Sag	100 ºC or ice loaded, final, whichever governs		
Rated Max Temperature	Short Term 127 ºC (<50 hrs per year); Continuous 93 ºC		
Design Fault Level and Duration	Wawa TS: 30 kA, Marathon TS: 30kA, Lakehead TS: 40kA Duration: 12 Cycles (for Breaker Fail)		
Line Design Load(for each circuit of the new double circuit line)	466 MVA Continuous at a voltage of 240 kV and at Limit Temp 93 ºC 599 MVA Contingency at a voltage of 240 kV and at Limit Temp 127 ºC (max 50 hrs/yr) (Based on the use of 1192.5 kcmil 54/19 conductors as assumed by the IESO in its Feasibility Study dated August 18, 2011)		
	Line Rating Parameters:	**Summer**	**Winter**
	Emmissivity of Conductor	0.6	0.6
	Absorptivity of Conductor	0.8	0.8
	Wind Velocity (m/s)	0.6	0.6
	Ambient Air Temperature (ºC)	30	10
	Elevation (m)	720	720
	Latitude (degrees North)	46	46
	Line Direction	East - West	East - West
	Day of Year	June 21	Dec. 21

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OPGW	
Type	**48 fiber single mode; Configuration to be determined**
Application	Communication/Lightning protection
Size	To be determined
Unit Mass (kg/m)	TBD
Outside Diameter (mm)	TBD
Area (mm^2)	TBD
Ultimate Tensile Strength (kN)	TBD
Installation	Self Supporting
Condition for Maximum Sag	50 ºC or ice loaded, final, whichever governs
Rating (kA^2*s)	TBD (215 ºC temperature limit, 50 ºC ambient)
OHSW	
Type	**To be determined by Proponent**
Application	Overhead Shield Wire
Size	TBD
Unit Mass (kg/m)	TBD
Outside Diameter (mm)	TBD
Area (mm^2)	TBD
Ultimate Tensile Strength (kN)	TBD
Condition for Maximum Sag	50 ºC or ice loaded, final, whichever governs
Rating (kA^2*s)	TBD based on fault current and OHSW type, 50 ºC ambient

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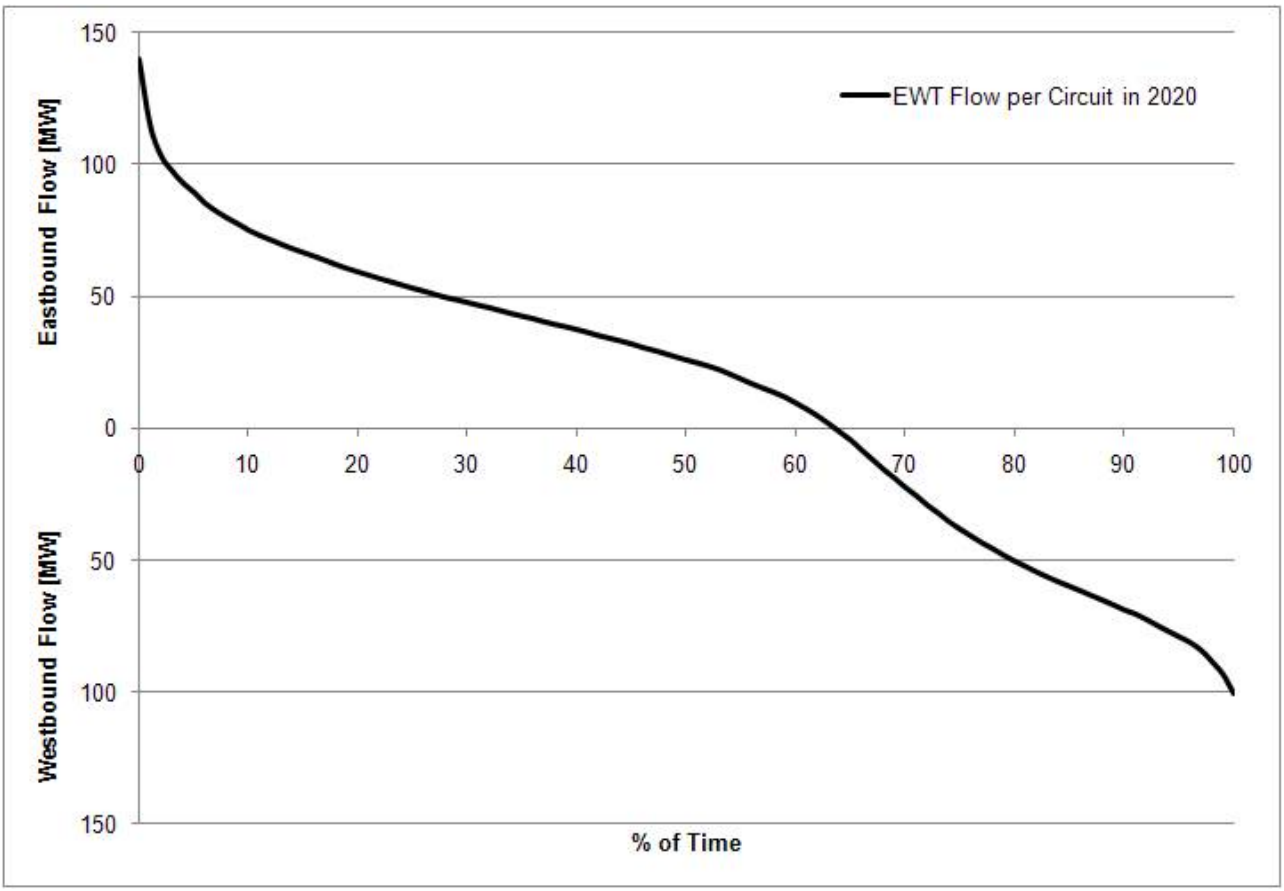
Optimization	(Values to be assumed for conductor optimization purposes)
Evaluation Period	25 Years
Year of Energization	2015
Energy Cost ($/MWhr)	$40 (Production Cost)
Inflation Rate	3% per annum for energy cost
AFUDC Rate	5.6% per annum
Discount Rate	7% per annum (for PV of Losses)

E-W Tie Duration Curve*



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**EWT flow duration curve, per circuit, in 2020 based on reference case with a new double circuit*

3. INSULATION						
3.1	**230 kV Phase Suspension and Strain Insulation Properties for Typical Strings (see note 10)**					
Type		**Porcelain**		**Toughened Glass**		
		14 x ANSI 52-5 NGK CA-501MR (Suspension)	**14 x ANSI 52-11 NGK CA-589MK (Dead-end)**	**14 x ANSI 52-5 Sediver N12/146 (Suspension)**	**14 x ANSI 52-11 Sediver N21/156 (Dead-end)**	**OEB (Min. Requirements)**
Section Length (m)		2.045	2.178	2.044	2.184	
Mass per Unit (kg)		5.4	8.8	4.0	7.2	
Leakage Distance (m)		4.09	5.33	4.48	5.32	3.98
60 Hz Dry Flashover (kV)		785	790	785	Not provided	
60 Hz Wet Flashover (kV)		565	545	565	Not provided	
Positive Critical Impulse Flashover - CIFO (kV)		1265	1330	1265	Not Provided	1155
Negative Critical Impulse Flashover - CIFO (kV)		1275	1330	1275	Not Provided	
Specified Mechanical Load/ANSI Strength (kN)		120	220	120	222	
Routine Test Load/M&E Strength (kN)		60	110	60	111	
Grading Rings		N/R	N/R	N/R	N/R	
3.2	**Guy Insulation**					
Type		**TBD – Generally not required for latticed steel construction.**				

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4. 230 kV AIRGAPS & INSULATOR SWING CRITERIA (Note [1])					
	CSA C22.3 No. 1-06	**60 Hz Flashover 5yr Gust (OEB)**		**Moderate Wind (OEB)**	**Uplift**
Loading Area[2]	-	-		-	-
Wind Pressure (Pa)	230	350		230	0
Conductor Temperature (ºC)	4	4		-30	-50
Conductor and Tension Condition	bare, final tension	bare, final tension		bare, final tension	bare, final tension
Minimum Air Gap (m)	1.586 Table A1	Phase to ground	Phase to Phase	1.20	N/A - No Uplift (+'ve weight)
		0.60	1.020[3]		

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5. STRUCTURAL DESIGN CRITERIA				
	C22.3 No. 1-06 Heavy Loading	**Cold Temperature**	**1/50 Year Return Wind Gust (HONi)**	**Static Ice Load (HONi)**
Zone	N/A	N/A	N. Ont.	N. Ont.
Radial Ice Thickness (mm)	12.5	0.0	0	25.0
Wind Pressure on Conductor (Pa)	400	0	770	0
Wind Pressure on Tower (Pa)	1200	0	2110	0
Ice/Snow Density (kg/m^3)	900	0	0	900
Temperature (ºC)	-20.0	-50.0	10.0	0

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6. LOAD AND STRENGTH FACTORS (OVERLOAD FACTORS FOR DETERMINISTIC LOADS - LF) [4]				
6a) Strength Factors for Reliability Based Design				
	SF Tangent	**SF Angle**	**SF Deadend**	**Remarks**
Metal Structures	1.0	0.9	0.9	
Support Hardware	1.0	1.0	0.9	
Guy Wire	0.9			
6b) Load Factors for Deterministic Design (with consideration for non-linear behavior)				
	Vertical	**Transverse**	**Longitudinal**	**Remarks**
Steel Towers	1.15	1.1	1.1	Minimum Grade of Construction - CSA C22.3 No.1-06 Grade 2 unless otherwise indicated. Stated LF's are for Grade 2 construction and are to be adjusted accordingly for alternate Grades.
Guy Assemblies	1.25			
Anchor in Soil	2.00			
Anchor Rod	1.25			
Insulators, including guy strains	2.00			

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7. SAG TENSION CRITERIA (Note 5)				
	Condition	**Maximum % UTS**	**Conductor Condition**	**Remarks**
Phase Conductor				
Tension limiting conditions	-30.0 ºC	25.0	Initial	OEB vibration limit
	3 ºC	35.0	Initial	CSA C22.3 No. 1-06 vibration guideline. OEB limit at -30 ºC condition will govern with its colder temperature criteria
	3 ºC	25.0	Final	CSA C22.3 No. 1-06 vibration guideline
	C22.3 No. 1-06 Heavy Loading	60.0	Final	CSA 22.3 No. 1-06 requirement
Overhead Shield Wire				
Tension limiting conditions	-30.0 ºC	25.0	Initial	OEB vibration limit
	3 ºC	20.0	Initial	CSA C22.3 No. 1-06 vibration guideline.
	3 ºC	15.0	Final	CSA C22.3 No. 1-06 vibration guideline. ISO 502.2 specifies 20% UTS
	C22.3 No. 1-06 Heavy Loading	60.0	Final	CSA C22.3 No. 1-06 requirement

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8. GROUND CLEARANCES (Note 6)				
Clearance Description	**Basic Clearance, Maintained [7]**		**Design Safety Factor (m) (OEB)**	**Total Design Clearance (m)**
	Code/Standard	**230 kV (m)**		
Roads and Alleys: Over land likely to be travelled by road vehicles (including highways, streets, lanes, alleys, and driveways other than to residences or residence garages)	CSA C22.3	6.1	1.2	7.3
Pipelines: Over the right of way of pipelines	CSA C22.3	6.1	1.2	7.3
Alongside land likely to be travelled by road vehicles or within the limits (with no overhang) of streets and highways	CSA C22.3	6.1	1.2	7.3
Agricultural: Across or along rural areas likely to be traveled by agricultural and other equipment	CSA C22.3	6.1	3.9	10.0
Alongside Roads unlikely to be traveled: by road vehicles within 1.5 m of the ROW	CSA C22.3	5.5	1.2	6.7
Approaches: Across or alongside driveways to residences or residence garages	CSA C22.3	6.1	1.2	7.3
Highways: Primary and Secondary highways, unless part of a high load corridor	CSA C22.3	7.9	1.2	9.1
High Load Corridor: high load corridor for unescorted 9 metre high loads		N/A		11.5
Extra High Load Corridor: High load corridor for unescorted 12.8 metre high loads		N/A		15.3
Railway: Above top of rails at railway crossing	CSA C22.3	9.0	0.6	9.6

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9. GROUND CLEARANCES, Navigable Waters				
Clearance Description	**Basic Clearance, Maintained**		**Design Safety Factor (m) (OEB)**	**Total Design Clearance (m)**
	Code/Standard	**230 kV (m)**		
Main lakes, main navigation routes H=14m	CSA C22.3	17.3	1.2	18.5
Large lakes, main rivers in resort areas H=12m	CSA C22.3	15.3	1.2	16.5
Small resort lakes, rivers connecting small lakes, crossings adjacent to bridges and roads H=10m	CSA C22.3	13.3	1.2	14.5
Very small isolated lakes and rivers H=8m	CSA C22.3	11.3	1.2	12.5

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10. STRUCTURE DATA					
Name	**Configuration**	**Structure Name**	**Structure Type**	**Typical Maximum Span (m)**	**Line Deflection (º)**
Tangent	Tangent – self supporting	TBD	Latticed Steel Tower	385	0-1˚
Light Angle	Light Angle – self supporting	TBD	Latticed Steel Tower	385	1-5˚
Medium Angle	Medium Angle – self supporting	TBD	Latticed Steel Tower	385	5-15˚
Heavy Angle	45 Degree Angle/DE – self supporting	TBD	Latticed Steel Tower	385	0-45˚
Deadend	90 Degree Deadend – self supporting	TBD	Latticed Steel Tower	385	0-90˚

11. FOUNDATIONS AND ANCHORS	
Foundation Type	To be determined. Alternatives will be considered based on encountered soil conditions. These may include concrete and earth grillages, cast in place concrete piles, rock anchors, and others.
Backfill Material for Excavated Foundations	Where excavated foundations are chosen, backfill will generally consist of the excavated soils if they are suitable for re-compaction. If not, imported fills will be considered.

12. GROUNDING AND BONDING	
General	Ground as per OEB Transmission Performance Specification.
Shield Wire / System Ground	Effectively grounded; Two shield wires and/or OPGW
Ground Resistance	Maximum tower ground resistance shall be 20 Ω or less unless otherwise specified.
Ground Rods	Ground rods and/or counterpoise may be required to obtain ground resistance.
Guys	Only where free standing towers are not used.
Hardware Bonding	As per OEB "Minimum Technical Requirements for the Reference Option of the East-West Tie"

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13. Lightning Protection	
Circuit Performance	Long term average number of circuit outages per 100 circuit miles per year < 3.0
Multi-Circuit Performance	Long term average number of multi-circuit outages per 100 circuit miles per year < 1.0
Max. Shield Angle	Double Circuit: 15 degrees maximum at the structure Single Circuit: 20 degrees maximum at the structure
Lightning Arrestors	N/A

14. Phasing	
Substation Terminations	System phase A connects with transformer primary bushing TBD from TFO records.
	System phase B connects with transformer primary bushing TBD from TFO records.
	System phase C connects with transformer primary bushing TBD from TFO records.

15. Right of Way, Setbacks, Power Line Marking, Bird Diverters	
230 kV Right of Way Width	Minimum 50 m for Greenfield construction fully on easement (for estimating purposes).
Aerial Markers	Aerial markers at highway, railway, pipeline right of way, and navigable water crossings to be in accordance with utility standard. Markers balls or cones to be in accordance with utility standard.
Roadway Setbacks	Generally a minimum of 15.3 m, may vary according to specific site requirements.
Aerial Boards	One aerial number board on every tenth tower and on the first / last tower in the transmission line.
Bird Diverters	Not anticipated at this time.

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16. MATERIALS	
General	Power line material based on standard utility stocked items where available.
Structures	To be determined - latticed steel transmission towers.
Dampers	Conductor: Spacer dampers for bundled conductor, Stockbridge-type for single conductor OPGW: Stockbridge-type, 2 dampers per span / OPGW. OHSW: Stockbridge –type.

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Notes:

[1] For Angle structures where the insulators are free to swing, the clearance requirements must be maintained with both forward and reverse wind and for both initial and final tensions.

[2] Loading areas yet to be defined for Ontario beyond those specified in CSA C22.3. Further analysis may be conducted.

[3] To be used for galloping clearances.

[4] Stated load factors are for non-linear analysis methods where buckling and p-delta effects are taken into account.

[5] Tension limiting conditions represent the maximum allowable tensions in a given ruling span. Tensions may be reduced below these values for uplift and/or structural reasons.

[6] Ground clearance requirements are based on CSA C22.3 No.1-06 "Overhead Systems", which are quoted in the left column and give the minimum acceptable clearances. The OEB adds a design buffer to these minimum clearances to arrive at the design clearances, given in the right column.

[7] Voltage indicated is phase to phase. Clearances are based on phase to ground voltage.

[10] Insulator string properties are obtained from data published by the manufacturers. Required insulator specification may vary on light and medium angle suspension structures pending detailed design.