Ontario Energy Board

Commission de l'énergie de l'Ontario

ONTARIO ENERGY BOARD

Minimum Technical Requirements for the Reference Option of the E-W Tie Line

November 9, 2011

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1. PURPOSE

1.1 The purpose of these Minimum Technical Requirements is to specify general design concepts to be used in the design and costing of the reference option of the E-W Tie transmission line (the "E-W Tie Line").

These Minimum Technical Requirements are supplemented by Appendix A to this document which provides further technical specifications for the reference option of the E-W Tie.

This document is not intended as a detailed design specification or as an instruction manual for the E-W Tie Line and this document shall not be used for those purposes. The designated transmitter, its employees or agents must recognize that they are, at all times, solely responsible for the design, construction and operation of the E-W Tie.

The review of a proposed plan for the E-W Tie Line by the Ontario Energy Board ("the Board") shall not be construed as confirming or endorsing the design or as warranting the safety, durability or reliability of the facilities that constitute the E-W Tie. The Board, including its employees and other representatives, shall not be responsible for the strength, adequacy of design or capacity of equipment built pursuant to the plan, nor shall they be responsible for any damage or injury to any person resulting from the operation of the facilities.

A finding by the Board that a plan meets these technical requirements does not mean, expressly or by implication, that all or any of the requirements of the law or other good engineering practices have been met by the designated transmitter, and such judgement shall not be construed by the designated transmitter or others as an endorsement of the design or as a warranty, by the Board or any of its employees.

2. GENERAL CONDITIONS

2.1.1 Any work on an existing transmitter's right of way or facilities shall be conducted in accordance with its safety and operational requirements.

2.1.2 Proposals to modify a transmitter's existing facilities must have prior approval from the transmitter before undertaking any site work on its facility or right of way.

2.1.3 The transmission line route must be as specified in the Ontario Energy Board approval, and any subsequent commitments made during the approval process.

2.1.4 All engineering design calculations and drawings shall be done by or under the supervision of a professional engineer registered with Professional Engineers Ontario.

2.1.5 As part of the filing requirements for an application for designation the following shall be filed with the Ontario Energy Board to form part of the public record:

- all proposed design assumptions, including but not limited to the line structure loadings and line design clearances;
- documentation of where the applicant seeks to differ from these technical requirements and evidence as to the equivalence or superiority for use of the proposed variance; and
- signed affidavit from an office of the licensed transmitter to confirm conformance with the technical requirements except as noted above.

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3. ENGINEERING

3.1 STANDARDS AND PROCEDURES

3.1.1 Unless otherwise specified by the Ontario Energy Board, relevant standards and procedures for the design and construction of transmission line facilities must be followed. These include, but are not limited to:

- CSA C22.3 No. 1, “Overhead Systems”
- CSA C22.3 No. 3, “Electrical Coordination”
- CSA C22.3 No. 6, “Principles and Practices of Electrical Coordination Between Pipelines and Electric Supply Lines”
- CSA C22.3 No. 60286, “Design Criteria of Overhead Transmission Lines”
- CSA O15-90, “Wood Utility Poles and Reinforcing Stubs”
- CSA O80 SERIES-08 – “Wood Preservation”
- CSA C108.3.1, “Limits and Measurement Methods of Electromagnetic Noise from AC Power Systems, 0.15-30 MHz”
- CAN/CSA-C411.1-10 – “AC Suspension Insulators”
- CSA C411.4-10, “Composite Suspension Insulators for Overhead Lines > 75 kV”
- CSA C57-98 (R2006), “Electric Power Connectors for Use in Overhead Line Conductors”
- CSA C83-96 (R2005), “Communication and Power Line Hardware”
- CAN/CSA-C61089:03, “Round Wire Concentric Lay Overhead Electrical Stranded Conductors”
- CAN/CSA-C60888:03, “Zinc-coated Steel Wires for Stranded Conductors”
- CAN/CSA-C60889:03, “Hard Drawn Aluminum Wire for Overhead Line Conductors”
- CSA G12, “Zinc-Coated Steel Wire Strand”
- CSA-C49.2-10, “Compact Round Aluminum Conductors Steel Reinforced (ACSR)”

- CSA-G164, "Hot Dip Galvanizing of Irregularly Shaped Articles"
- G40.20-04/G40.21-04 (R2009) – "General Requirements for Rolled or Welded Structural Quality Steel/ Structural Quality Steel"
- ASME-BPVC-SEC 2C-2010 - Section 2 - Materials - Part C – "Specifications for Welding Rods, Electrodes, and Filler Metals"
- ASCE 10-97, " Design of Latticed Steel Transmission Structures"
- ASCE 48-05, "Design of Steel Transmission Pole Structures"
- ASCE 74, "Guidelines for Electrical Transmission Line Structural Loading"
- ASTM A394, "Standard Specification for Steel Transmission Tower Bolts, Zinc-Coated and Bare
- ASTM A572, "Standard Specification for High-Strength Low-Alloy Columbium-Vanadium Structural Steel
- IEEE 751, "Trial Use Design Guide for Wood Transmission Structures"
- IEC 61897, "Requirements and Tests for Stockbridge Type Aeolian Vibration Dampers"

3.1.2 The designated transmitter shall prepare an engineering field survey (plan and profile) of the full length of the line. The profile drawings shall have a horizontal scale of 1:2000 and a vertical scale of 1:200. Side hill elevations at fixed distances left and right of the centerline must be included where appropriate on the profile drawing. These drawings must also include property limits, location of waterways, railways, roads, other overhead lines, or any other obstructions that may dictate conductor clearances or require special clearance considerations. The survey data shall be provided in electronic format that is suitable for import by the computer software, "PLS-CADD", for line layout.

3.1.3 The designated transmitter shall obtain the necessary right-of-way for the line. All guy wires and anchors must be located within the right-of-way. The right of way shall be of sufficient width that horizontal deviation due to conductor swing plus flashover clearance specified for conductor blow out in Appendix A for the line shall be maintained entirely within the right of way for maximum span length. Additional width shall be provided where necessary to address separations between paralleling lines, railways, buildings/structures, or other installations and to meet construction, maintenance, operation, and any environmental requirements.

3.1.4 Minimum safe clearances must be provided between the transmission line conductors and ground, trees, railways, waterways, buildings, other overhead lines and other installations. These shall be as specified in Appendix A.

3.1.5 When in close proximity to or crossing railways, airports, navigable waterways, pipelines, highways, roads, etc., special clearances or other requirements as established by the owners or governing authority of those facilities may be required. These clearance or other requirements must be adhered to in the design and construction of the transmission line.

3.2 CONDUCTOR SELECTION

3.2.1 The conductor must meet the requirements specified by the Independent Electricity System Operator (the "IESO").

3.2.2 For alternating current transmission lines, the conductor's minimum diameter and bundle configuration will be chosen such that the surface voltage gradient at maximum line voltage does not exceed 18 kV/cm.

3.2.3 For transmission lines rated at 230kV and above, having a length greater than 50km, a complete line optimization study shall be performed to determine the most economical conductor configuration. At a minimum, this study must consider:

- Tower and foundation costs
- Span length
- Environmental load cases
- Conductor costs
- High, low, and most probable load growth scenarios
- Present value of losses

and other factors as appropriate. Study period shall be for a minimum of 25 years of operation.

3.2.4 Overhead shield wire must be designed to provide lightning protection, line grounding, and to carry the fault current on the line. The ground fault current and duration are as specified in Appendix A. Maximum shield angles are as specified in Appendix A.

3.2.5 When multiple shield wires are used, sharing of the fault current between them may be considered in computing temperature. Maximum fault temperatures to be used for I^2t

ratings are as follows for alternate products:

Product	Maximum Temperature (^{o}C)
Galvanized Steel (CSA G12)	400
Aluminum Coated Steel	600
Copper Coated Steel	1000
ACSR	400
All Aluminum Conductor	340
OPGW	215

Table 1: Allowable Maximum Temperatures for Shield Wires

3.2.6 Although shield wires are a general requirement for Ontario network facilities, there may be special circumstances where removal of the shield wire is necessary over short line segments. This is often the case for transmission line crossings. Regardless, removal of the shield wire for short segments should be done in such a manner that it does not result in a significant increase in lightning related outages to the line facility.

3.3 INSULATION SELECTION

3.3.1 The transmission line shall be insulated with either ceramic type insulators that meet the requirements of CSA C411.1 or non-ceramic type insulators meeting the requirements of CSA C411.4.

3.3.2 Non-ceramic insulators shall be provided with suitable grading rings for corona protection.

3.3.3 Non-ceramic insulators shall be capable of withstanding high-pressure water washing.

3.3.4 For ceramic loop (jumper) support strings, one cotter key with an anti-interference spring is required at the line end. For non-ceramic loop support strings, two cotter keys with anti-interference springs are required at the line and structure ends.

3.3.5 Minimum impulse insulation levels for a 230kV transmission line are as shown in table 2. Critical impulse flashover (CIFO) levels in the table are computed from standard BIL requirements as per the relationship: CIFO = BIL/0.91

Nominal Voltage (kV)	System Basic Impulse Level (kV)	Critical Impulse Flashover (kV)
230	1050	1155

Table 2: Minimum Insulation Levels for Standard Nominal Voltages

3.3.6 Minimum insulation leakage requirements are project specific and are as specified in Appendix A.

3.4 LINE HARDWARE CRITERIA

3.4.1 All line hardware shall meet the requirements of CSA C83-96 with forged hardware meeting the energy absorption level 2. Ferrous line hardware subject to tensile loads must be forged components or fabricated from structural steel with similar energy absorption capability.

3.4.2 Hardware galvanization shall meet the requirements of CSA G164.

3.4.3 Yield strength and reusability torque are as defined in CSA C83-96.

3.4.4 All hardware shall be corona free at the maximum operating voltage of the transmission line.

3.4.5 Conductor and Overhead Shield Wire splices, dead ends, and terminals shall be either compression or implosive-type. Optical Ground Wire (OPGW) may have alternate hardware arrangements, but the alternate arrangements must be demonstrated to be equivalent or superior for use by the applicant for designation.

3.5 AEOLIAN VIBRATION CONTROL

3.5.1 For standard ACSR conductors and galvanized steel shield wire:

- the initial tension must not exceed twenty-five percent (25%) of the conductor’s rated tensile strength under a winter design temperature of minus thirty (-30) degrees Celsius; and

- the final tension of the conductor must not exceed twenty percent (20%) of the conductor's rated tensile strength under the temperature of fifteen (15) degrees Celsius.

3.5.2 Stockbridge-type vibration dampers are to be used on single conductor configurations. Vibration control on bundled conductors is to be achieved with spacer dampers. The design and location of stockbridge dampers and spacer dampers must account for conductor tension, span length, and terrain exposure.

3.5.3 Stockbridge-type vibration dampers are to be used for overhead shield wire.

3.5.4 Use of spacer dampers with two-part metal conductor clamps bearing directly on aluminum conductor is not acceptable. Use of elastomer lined clamps is preferred.

3.5.5 Use of damping devices which significantly restrict heat dissipation and reduce thermal capacity of the line are not acceptable.

3.6 TRANSMISSION STRUCTURE DESIGN

3.6.1 Structure designs will be latticed steel tower, steel pole, or wood pole design unless an alternate structure is demonstrated to be equivalent or superior for use by an applicant for designation.

3.6.2 Structures are to be designed suitable for live line maintenance. Phase to phase, phase to structure, phase to ground, and phase to ground wire shall be determined with consideration for live line work.

3.6.3 Structures are to be designed to meet the load combination requirements specified in Appendix A, with the specified load and strength factors, without permanent set in any member.

3.6.4 Galloping clearances are to be considered in development of the general structure configuration for voltages at or above 230kV. This analysis shall consider single loop galloping, regardless of span length, with a primary axis limited to a maximum of 12m (Lilien & Havard, Cigre TF B2.11.06).

3.6.5 For wood pole structures:

- galvanized steel must be used for cross-arms and cross-bracing;
- wood pole classification and strength shall be as per CSA O15;
- all wood poles shall be pressure treated with preservative as per CSA O80.4 ; and
- all structural steel shall meet the requirements of CSA G40.21 or ASTM A572.

3.6.6 For tubular steel structures:

- design and fabrication shall be in accordance with ASCE 48-05;
- deadend and medium or heavy angle structure deflections shall be limited to a maximum of 3% of pole length beyond any manufactured camber; and
- tangent structure deflections shall be limited to a maximum 9% of pole length.

3.6.7 For latticed steel structures:

- Design, testing, and fabrication shall be in accordance with ASCE 10-97;
- all structural steel shall meet the requirements of ASTM A572 for all primary elements;
- all bolts shall meet the requirements of ASTM A394;
- specified wind loads on towers are to be applied to 1.5 times the projected area of one face;
- If the design of new family of latticed steel towers is required, then full scale load testing shall be performed on all members of the tower family.

3.6.8 Heavy angle structures for line deflections greater than 30 degrees, using strain insulator configurations, and termination structures must be designed for possible use as a full one-way deadend with all conductor and shield wire tensions applied to one face of the structure.

3.6.9 Where guys and anchors are used to support transmission structures they must use galvanized steel wire in compliance with CSA G12.

3.6.10 Steel members within 15 degrees of horizontal must be designed with sufficient bending capacity to accommodate a 1.35 kN concentrated load at any point along its length to simulate the weight of a worker and tools. These concentrated loads shall be multiplied by the load factor specified in Appendix A for construction and maintenance loads and will be applied in addition to any other loads.

3.6.11 Transposition structures, if necessary, will be designed and constructed to accommodate the transposition arrangement.

3.6.12 Transmission structure foundations and anchors must be designed for the full design capacity of the tower, regardless of its specific usage, with a load factor of 1.2.

3.6.13 All structures shall be designed, fabricated, and installed in accordance with good utility practice.

3.7 TRANSMISSION LINE BONDING AND GROUNDING

3.7.1 Overhead shield wires shall be effectively bonded to the steel structures through jumpers at all structures. Jumper loops shall be provided at all overhead ground wire dead-end assemblies and be connected to the steel structures. Provision shall be made for grounding the structures by having an additional hold for a structure bolt on each leg above the ground line.

3.7.2 The grounding requirements for line structure will depend on the soil resistivity along the line route. The ground resistance of each structure shall be measured without the overhead ground wire connected to the structure.

3.7.3 Where additional grounding arrangement is required to reduce the structure ground resistance, ground rods and/or counterpoise grounding arrangements may be used. The counterpoise wire shall be buried below grade. At locations where overhead ground wires are not installed, continuous counterpoise wires of equivalent ground fault current capacity are required to maintain grounding continuity between line structures.

3.7.4 Overhead shield wire shall be dead-ended with a ceramic insulator to the station entrance structure. An insulated down-lead cable shall be provided to connect the overhead ground wire to the station ground grid.

3.7.5 Bonding is required between all metallic hardware and all metallic components of a wood pole structure, overhead ground wire and structure grounds. Copper-clad steel conductor must be used for the “downlead” bonding on each pole.

3.8 AS-BUILT DOCUMENTATION

3.8.1 The following final drawings and technical information of the design of the E-W Tie Line must be maintained by the owner and operator of the transmission line in both electronic and hard-copy formats. All drawings shall be sealed and approved by a Professional Engineer, registered with Professional Engineers of Ontario.

- Line survey data, suitable for PLS-CADD structure spotting program
- Line layout design with the PLS-CADD model, including the "backup" files generated by the PLS-CADD program
- Plan and profile data and drawings. Drawings will include conductor profile at maximum sag, structure type, height and adjustment, ruling span, insulator type and rating, design tension of conductor and overhead ground wire under combined ice and wind condition for each line section, etc.
- Sag and tension calculations including stringing data for conductor and overhead ground wire for each line section
- Hardware assembly drawings with material list
- Insulator technical specifications
- Structure design, details and erection drawings and design calculations including PLS-POLE and/or PLS-TOWER models, i.e., the "backup" files
- Geotechnical Reports
- Footing drawings and design calculations
- Guy Anchor drawings and design calculations
- Grounding design data including measured soil resistivity and structure footing resistance at each line structure location
- Calculations and drawings for step and touch potential control where applicable
- Phasing arrangement drawing
- Electric and magnetic fields calculations
- Electromagnetic induction and mitigation calculations to railways and pipelines where applicable
- Vibration damper application data
- Records of signs and markers installation. Design and drawings of markers as per Clause 5.8, if applicable
- Approved crossing drawings for railway, navigable water-way, highway and pipeline crossings, where applicable (drawings shall include stamp from

approving authority)

- Other "As Constructed" information for the new line including sags, structure types, heights, insulator types & ratings, foundations, GPS co-ordinates and digital images at each line structure location and other technical information
- Quality assurance documentation identifying all field checks conducted and results of those checks

4. ENVIRONMENTAL AND RIGHT-OF-WAY

4.1 COMMITMENTS

4.1.1 All work shall be executed in accordance with the commitments made during the Environmental Assessment process .

4.2 ENVIRONMENTAL LEGISLATION

4.2.1 All work shall comply with the following legislation, as well as all other applicable legislation, by-laws, etc. to minimize the potential for any significant, adverse environmental effects and associated liability, fines or charges during construction:

Legislation	Administering Agency
Federal Legislation	
Aeronautical Act	Transport Canada
Canada Transportation Act	Transport Canada
Explosives Act	Natural Resources Canada
Fisheries Act	Fisheries and Oceans Canada/Conservation Authority
Migratory Birds Convention Act	Environment Canada
Navigable Waters Protection Act	Transport Canada
Railway Safety Act	Transport Canada
Species at Risk Act	Environment Canada
Transportation of Dangerous Goods Act	Transport Canada
Provincial Legislation	
Conservation Authorities Act	Conservation Authorities
Crown Forest Sustainability Act	Ministry of Natural Resources
Endangered Species Act	Ministry of Natural Resources
Environmental Protection Act	Ministry of the Environment
Fish and Wildlife Conservation Act	Ministry of Natural Resources
Forest Fire Prevention Act	Ministry of Natural Resources
Lakes and Rivers Improvement Act	Ministry of Natural Resources
Niagara Escarpment Planning and Development Act	Niagara Escarpment Commission
Ontario Heritage Act	Ministry of Culture
Ontario Water Resources Act	Ministry of the Environment
Planning Act	Ministry of Municipal Affairs and Housing
Provincial Highways Act	Ministry of Transportation

Public Lands Act	Ministry of Natural Resources

Table 3: Legislation and Administering Agencies

Ontario Energy Board

Commission de l'énergie de l'Ontario

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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

Appendix A – Minimum Design Criteria for the Reference Option

Date: November 9, 2011

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

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

Appendix A – Minimum Design Criteria for the Reference Option

Date: November 9, 2011

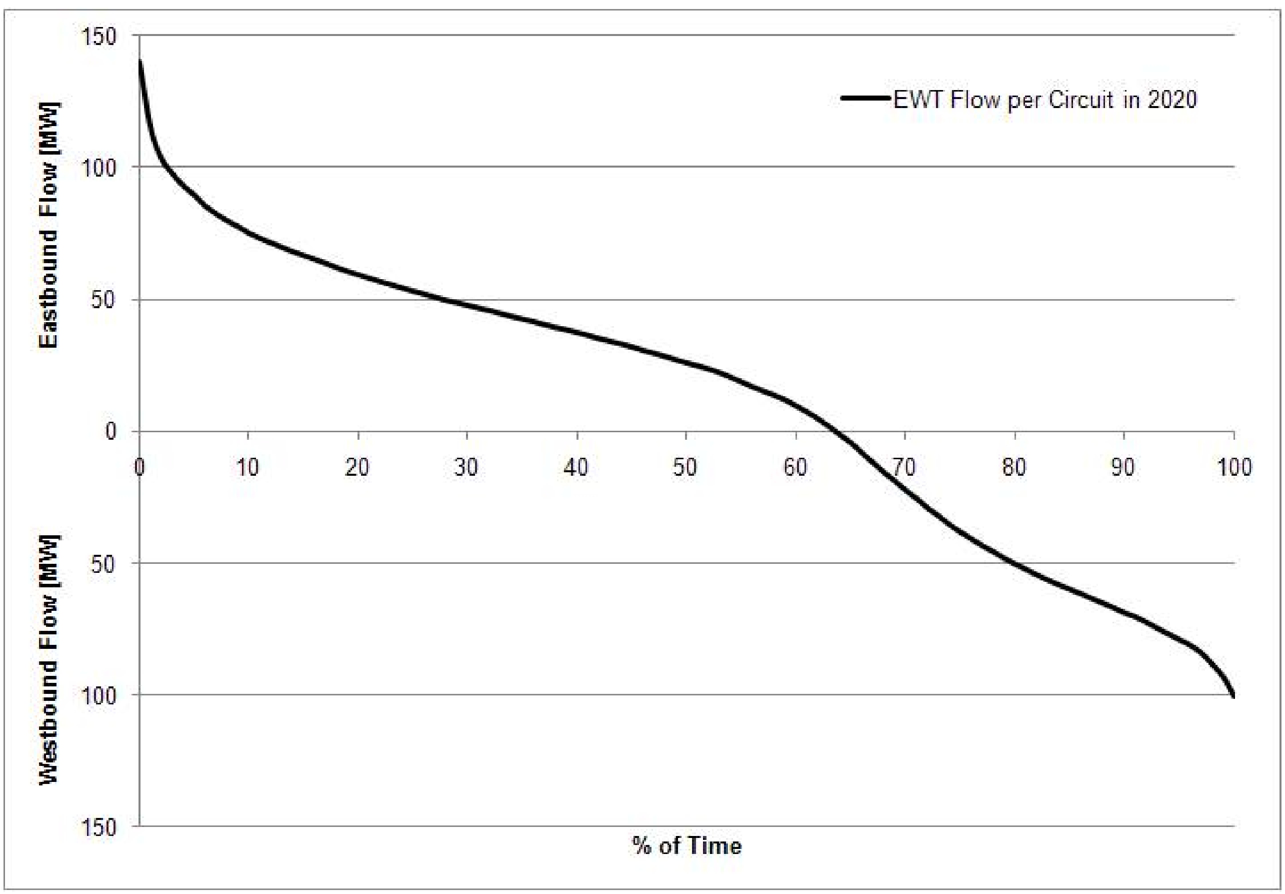
OPGW	
Type	**48 fiber single mode; Configuration to be determined**
Application	Communication/Lightning protection
Size	To be determined
Unit Mass (kg/m)	TBD
Outside Diameter (mm)	TBD
Area (mm^2)	TBD
Ultimate Tensile Strength (kN)	TBD
Installation	Self Supporting
Condition for Maximum Sag	50 ºC or ice 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

Appendix A – Minimum Design Criteria for the Reference Option

Date: November 9, 2011

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*



**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.**				

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]		

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

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	
Guy Assemblies	1.25			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.
Anchor in Soil	2.00			
Anchor Rod	1.25			
Insulators, including guy strains	2.00			

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

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

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

Appendix A – Minimum Design Criteria for the Reference Option

Date: November 9, 2011

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"

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.

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.

Notes:

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[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.*