PJM DESIGNATED ENTITY DESIGN STANDARDS

1.0 PURPOSE

These standards establish design criteria to provide a minimum level of performance for new competitively solicited facilities.

These standards represent the minimum criteria by which a competitively solicited facility must be designed by the Designated Entity unless more stringent requirements are specified in the Project Statement Requirements Document (PSRD). These standards facilitate the design of transmission line facilities in a manner that is compliant with NERC requirements and PJM criteria; are consistent with Good Utility Practice, as defined in the XXX; and are consistent with current industry standards specified herein, such as NESC, IEEE, ASCE, CIGRE, and ANSI, at the time the PSRD is issued.

Comment [TDP1]: As rewritten during 2/8 call.

Comment [TDP2]: Alternative language to the previous paragraph from SPP, modified to fit our document.

Comment [TDP3]: Verify title.

Comment [TDP4]: Insert appropriate PJM document name.

2.0 SCOPE

This document sets forth the minimum requirements for the design of overhead electric transmission line facilities rated 69kV and above for projects solicited through the PJM competitive process. These minimum design standards do not apply to projects that are not associated with the PJM competitive process.

3.0 GENERAL REQUIREMENTS

The design of all transmission lines shall meet or exceed the requirements of this document, the National Electrical Safety Code (ANSI/IEEE C-2) [NESC] in effect at the time of the project design, and all additional legislated requirements as adopted by governmental jurisdictions. It shall be the responsibility of the Designated Entity to identify all additional legislated requirements. In the event of conflicts between documents, the most stringent requirement shall apply.

4.0 CONDUCTOR

The Designated Entity shall determine normal and emergency ratings for both summer and winter seasons using an appropriate facility rating methodology. The Designated Entity shall provide documentation of the calculation method, including all assumptions for the input parameters. The conductor selected shall be compatible with all ampacity ratings.

The loss of strength of the conductor shall be limited to 10% of its initial rated breaking strength for an assumed 40 year life. Conductor connectors and accessories shall have mechanical strength and thermal capabilities compatible with the conductor.

The damaging effects of Aeolian vibration shall be appropriately mitigated. Mitigation measures may include lower design tensions, mechanical vibration dampers, and spacer dampers for bundled conductor.

5.0 LOADING AND STRENGTH REQUIREMENTS

Transmission Line Facilities shall have sufficient strength to resist the individual and cumulative effects of all load cases defined in Section 5.1, including all subsections. The applied loads shall be adjusted by the Load Factors defined in the subsections of Section 5.1, and the material strengths shall be adjusted by the material strength reduction factors specified by the applicable governing industry publications referenced in Section 5.2.

Transmission Line Facilities include all supporting structures, conductors and other wires, insulators, hardware, and foundations.

5.1 Design Load Requirements

All Transmission Line Facilities shall be designed to withstand the independent load cases defined in Sections 5.1.1 through 5.1.7. The effects of gravity, wind, ice, wire tension, construction, and maintenance loads shall be included as applicable.

5.1.1 Legislated Loads

5.1.1.1 Transmission Line Facilities shall be designed to resist the loading conditions defined in Rules 250B, 250C, and 250D of the NESC. For Rule 250B, the provisions of Grade B construction and the Heavy loading district shall be applied. The provision of Rules 250C and 250D permitting the exclusion of structures less than 60 feet in height shall not apply.

5.1.1.2 The Designated Entity shall identify and design to all additional legislated requirements as adopted by governmental jurisdictions.

5.1.2 Extreme Wind

Transmission Line Facilities shall be designed to resist the wind loads corresponding to a 100 year return period (RP) as defined in the latest edition of ASCE Manual of Practice (MOP) 74.

Wind pressures shall be calculated in accordance with the procedures of the latest edition of ASCE MOP 74, properly adjusted for structure shape, gust, and height. The Load Factor applied shall be a minimum of 1.0.

Wind loads shall be applied in the direction producing the maximum loading effect.

All wires shall be assumed intact.

5.1.3 Concurrent Ice with Wind

Transmission Line Facilities shall be designed to resist the ice loads resulting from freezing rain corresponding to a 100 return period and the associated concurrent wind loads as defined in the latest edition of ASCE MOP 74.

Wind pressures shall be calculated in accordance with the procedures of the latest edition of the ASCE MOP 74, properly adjusted for structure shape, gust, and height. The Load Factor shall be a minimum of 1.0.

Wind loads shall be applied in the direction producing the maximum loading effect.

The weight of ice shall be considered 57 pounds per cubic foot. The temperature used shall be either the values specified or 32°F. The Load Factor shall be a minimum of 1.0.

All wires shall be assumed intact.

5.1.4 Heavy Ice

Transmission Line Facilities shall be designed to resist ice loads resulting from freezing rain, snow, and in-cloud icing as defined in Sections 5.1.4.1 through 5.1.4.4.

In each case, the weight of ice shall be considered 57 pounds per cubic foot, the temperature 0°F, and the wind speed 0 mph. The Load Factor shall be a minimum of 1.0. All wires shall be assumed intact.

5.1.4.1 Transmission Line Facilities shall be designed to resist the effects of a minimum of 1.0 inch radial ice resulting from freezing rain applied to all wires. Transmission Line Facilities designed for voltages 230kV and greater shall also meet the requirements defined in Sections 5.1.4.2, 5.1.4.3, and 5.1.4.4.

5.1.4.2 Transmission Line Facilities designed for voltages 230kV and greater and constructed in the following states/districts or portions thereof, shall be designed to resist the effects of a minimum of 1.5 inches radial ice resulting from freezing rain applied to all wires.

- District of Columbia
- New Jersey
- Pennsylvania, within 100 miles of the coast of the Atlantic Ocean
- Delaware, within 75 miles of the coast of the Atlantic Ocean
- Maryland, within 75 miles of the coast of the Atlantic Ocean

5.1.4.3 Transmission Line Facilities designed for voltages 230kV and greater and constructed in regions with a ground elevation greater than 1500 feet and less than 3000 feet above mean sea level shall be designed to resist the effects of a minimum of 1.25 inch radial ice resulting from freezing rain applied to all wires. Greater values shall be considered in areas known to accumulate larger amounts of ice resulting from freezing rain, or are prone to in-cloud icing or accumulation of snow, and when indicated by historical weather data or site-specific ice studies.

5.1.4.4 Transmission Line Facilities designed for voltages 230kV and greater and constructed in regions with a ground elevation greater than 3000 feet above mean sea level shall be designed to resist the effects of a minimum of 1.5 inch radial ice resulting from freezing rain applied to all wires. Greater values shall be considered in areas known to accumulate larger amounts of ice resulting from freezing rain, or are prone to in-cloud icing or accumulation of snow, and when indicated by historical weather data or site-specific ice studies.

5.1.5 Unbalanced Longitudinal Load Cases

Except as described in Section 5.1.5.1, Transmission Line Facilities designed for voltages 230kV and greater shall be designed to withstand longitudinal loads due to broken wire and differential ice conditions as described in Sections 5.1.5.~~1~~ 2 and 5.1.5.~~2~~3.

Except as described in Section 5.1.5.1, Transmission Line Facilities designed for voltages less than 230kV may be designed to withstand longitudinal loads due to broken wire and differential ice conditions as described in Sections 5.1.5.~~1~~ 2 and 5.1.5.~~2~~3.

5.1.5.1 These unbalanced load cases do not apply to wood structures or structures comprised of preengineered poles ("wood pole equivalents") designed for voltages less than 230kV. They also do not apply to insulators; however, insulators must be designed such that they do not detach from the supporting structure.

5.1.5.~~1~~ 2 Broken Wire Loading

For single conductor phase configurations of both single and multiple circuit structures, only one conductor or one shield wire shall be considered broken in each load case. Each wire shall be broken individually to ensure the maximum loading effect is determined for each component. For the design of suspension structures, the conductor tensions may be reduced by the effects of longitudinal insulator displacement.

For phase configurations with more than one sub-conductor of both single and multiple circuit structures, a minimum of one sub-conductor or one static wire shall be considered broken. Each phase shall be evaluated with one broken sub-conductor to ensure the maximum loading effect is determined for each component. For the design of suspension structures, the swing of the insulator assembly shall be ignored, resulting in a longitudinal load imbalance equal to the tension of one sub-conductor subjected to the appropriate environmental conditions.

The minimum environmental load condition shall be 0.5 inch of ice, 40 mph wind, and 32°F. The Load Factor shall be a minimum of 1.0.

5.1.5.~~2~~3. Differential Ice Loading

With all wires assumed intact, each conductor and shield wire on one side of the structure shall be loaded with 0.5 inch of radial ice and 40 mph wind at a temperature of 32°F. All conductors and shield wires on the other side of the structure shall be loaded with the specified wind only. The weight of ice shall be

Comment [TDP5]: Need to discuss this relative to wood structures. Should wood be designed to anything other than NESC?

How about excluding wood from the longitudinal loading requirements for below 230kV?

considered 57 pounds per cubic foot. The Load Factor shall be a minimum of 1.0.

For the design of suspension structures, the conductor tensions may be reduced by the effects of longitudinal insulator displacement.

5.1.6 Construction and Maintenance Loads

Transmission Line Facilities shall be designed to facilitate complying with OSHA requirements related to climbing and fall protection, and the provisions of this section.

5.1.6.1 Bound Stringing Block

Transmission Line Facilities designed for voltages greater than 230kV shall be designed to resist longitudinal loads simulating a bound stringing block.

With all wires assumed intact, any one shield wire or phase conductor (or all sub-conductors of any one phase) shall be assumed to bind in a stringing block during installation. The block is assumed to swing 45°in-line. The wind load shall be 2 pounds per square foot with no ice at a temperature of 30°F. The Load Factor shall be a minimum of 1.5.

Comment [PSG6]: I would assume a stringing tension of 50% of the sagging tension. Applying a 28 mph wind seems severe. Again, does each structure component have to withstand this load without damage?

5.1.6.2 Climbing and Working Loads

In areas where climbing or work activites are reasonably anticipated, members of structures shall be designed to support a point load of ~~350~~ 250 pounds ~~to accommodate construction or maintenance activities~~. The Load Factor shall be a minimum of 1.5.

Comment [TDP7]: ASCE-74 (not 10) specifies a point load of 250 pounds times a load factor of 1.5 (not 1.0). I'm OK with 2.0. Sorry for the mix up.

5.1.7. Foundation Loading

Foundation reactions shall be determined from the load cases presented in Section 5.1. Load Factors shall be a minimum of 1.0.

5.2 Strength Requirements

Transmission Line facilities shall meet the strength requirements specified in Sections 5.2.1 through 5.2.3.

5.2.1 Strength Design Standards & Guides

Structures and foundations shall be designed to the requirements of the applicable publications:

- *ASCE Standard No. 10, Design of Latticed Steel Transmission Structures*
- *ASCE Standard No. 48, Design of Steel Transmission Pole Structures*
- *ASCE Manual No. 91, Design of Guyed Electrical Transmission Structures*

- *ASCE Manual No. 74, Guidelines for Electric Transmission Structural Loading*
- *ASCE Manual No. 104, Recommended Practice for Fiber-Reinforced Polymer Products for Overhead Utility Line Structures*
- *ASCE Manual No. 123, Prestressed Concrete Transmission Pole Structures*
- *ANSI 05-1, Specifications and Dimensions for Wood Poles*
- *IEEE Std. 691, Guide for Transmission Structure Foundation Design and Testing*
- *IEEE Std. 751, Trial-Use Design Guide for Wood Transmission Structures*
- *ACI 318 Building Code Requirements for Structural Concrete and Commentary*

5.2.2 Line Cascading Mitigation

To avoid cascading failures, structures shall be designed to withstand the unbalanced longitudinal load cases of Section 5.1.5, or an anti-cascading structure shall be placed every 5 miles.

5.2.3 Geotechnical Requirements

A geotechnical investigation shall be the basis of the final foundation design parameters.

6.0 ELECTRICAL DESIGN PARAMETERS

Conductor selection and configuration, including conductor size and the number of sub-conductors, shall consider electrical system performance parameters such as voltage, stability, losses, impedance, corona, electric and magnetic fields, audible noise, and television and radio interference. To correct for voltage imbalance, the phases may be transposed.

The estimated levels of audible noise and EMF values shall not exceed those required by governmental jurisdictions. These estimated values shall be determined by calculations specific to the proposed transmission facility.

7.0 RIGHT-OF-WAY

Rights of way shall be proportioned so that NESC horizontal clearances to buildings are maintained at the edges. Widths shall be calculated with the wires displaced from rest by a 6 psf wind at 60°F with no ice and at final sag. Deflection of flexible structures and insulator swing shall be considered where appropriate. The Designated Entity shall ensure that the right of way width meets their Vegetation Management clearance guidelines to ensure compliance with NERC FAC-003 requirements.

Consideration shall be given to acquiring uniform right of way widths.

8.0 INSULATION, LIGHTNING PERFORMANCE, & GROUNDING

Insulation, grounding, and shielding of the transmission system (line and station) shall be coordinated between the Designated Entity and the Transmission Owner(s) to which the project interconnects to promote acceptable facility performance. The resulting design shall approach the targeted lightning performance defined below.

The Designated Entity shall specify transmission line insulation levels that promote the ~~safe and~~ reliable operation of the line(s) under normal operation and surge events. Shielding and grounding ~~and footing ground resistance~~ shall be coordinated ~~designed~~ by using an appropriate analysis method ~~to~~ such that~~verify that the line design will result in~~ the following targeted lightning performance is approached.

- Voltages 345kV and greater – 1 Outage/100 circuit miles/Year
- 230kV – 2 Outage/100 circuit miles/Year
- 138/115kV – 3 Outage/100 circuit miles/Year
- 69kV – ~~1~~ 4 Outage/100 circuit miles/Year

Surge arresters, if installed, shall be applied in a manner that reduces the likelihood that the arrester or any of its associated hardware will interfere with reliable normal operation of the line in the event of surge arrester electrical or mechanical failure.

9.0 CLEARANCES

9.1 General

Unless otherwise stated, all clearances shall meet or exceed those defined in the NESC.

Clearances shall be maintained applying the maximum operating voltages ~~as~~ defined in PJM Manual 3, "Baseline Voltage Limits", Exhibit 3, Section 3.3.1. The circuit transient overvoltage (TOV) shall be used when considering the alternate clearances permitted by NESC Rules 232D, 233C3, 234H, 235B3.

~~For conductor-to-conductor clearances between different circuits and where~~When ~~the line~~a proposed transmission line ~~under~~ ~~design is crossing~~crosses over an existing supply or communication line, the position of the lower ~~conductors' conductors'~~wire ~~position~~ shall be determined by a straight line between ~~conductor~~ attachment points, unless specific sag/tension information for the lower ~~conductors/cables~~wires are known. When the sag/tension characteristics of the lower ~~conductors/cables~~wires are known, the ~~conductor~~environmental requirements of the NESC rules may be applied.

9.2 Live Line Maintenance Requirements

Adequate clearances shall be provided when live-line maintenance requirements are specified for a line design for any of the following maintenance activities:

- Climbing inspection

Comment [TDP8]: Alternative language.

Comment [TDP9]: Original text, modified by AEP.

At the end of the 2/8 call, those remaining agreed that either was acceptable. We will choose during the 2/16 call.

Dean to provide more background on his comment.

Comment [TDP10]: If we keep this version, suggest deleting. The analysis is implied with the coordination.

Comment [TDP11]: The new TSS document proposes 3, but 4 seems more realistic for 69kV.

Comment [PSG12]: IEEE 1313.2-1999 provides guidance on shielding failures in section 6.3.1.1—"typical design value of the SFFOR is approximately 0.05 flashovers/100 km-yr." Section 6.3.1.2 provides a target for BFR for 345kV and 500kV lines of 0.3 to 0.6 flashovers/100km-yr. BFR for 138 and 230kV may range from 0.6 to 2 whereas lower voltage lines may have BFR's of 4 to 15 flashovers/100km-yr.
The flashover rate depends on air gaps, shielding, ground flash density, and soil resistivity (structure grounds). In my experience, to achieve 1 outage/100 miles per year, you need to have good grounds and air gaps that are on the order of 345kV or 500kV structures. I would think PJM knows what performance each utility has, and has an expectation of what is achievable in their territory without extraordinary means, or having to install arrestors on every structure. It would help if PJM would provide information on what distribution of ground rod readings to utilize for the analysis.

Comment [TDP13]: Do we mean environmental loading characteristics.

- Hot stick maintenance for the specified line components
- Live line maintenance for the specified line components ~~utilizing~~using specified lift equipment
- Helicopter live line maintenance for the specified line components ~~utilizing~~using the specified helicopter

All live line maintenance clearances shall be determined using the OSHA calculation methods for the specified circuit TOV, ~~and~~ breaker design, and maintenance program.

Comment [PSG14]: I assume that the solicitation would provide the TOV to assume for a bid, if live line maintenance is required, under the conditions that live line maintenance is performed.

9.3 Vertical Clearances

The vertical conductor clearances of Section 23 of the NESC shall be maintained at the NESC stated conditions ~~unless modified in Sections 9.5~~. All terrain points under the conductors shall be considered ~~vehicle-accessible~~to be traversable by vehicles ~~accessible~~. The buffers defined in Section 9.5 shall be applied.

9.4 Horizontal Clearances

The horizontal conductor clearances of Section 23 of the NESC shall be maintained at the NESC stated conditions ~~unless modified~~. The buffers defined in ~~Sections~~Section 9.5 shall be applied. ~~unless modified in Sections 9.5.~~

9.5 Clearance Buffers

Comment [TDP15]: The way this is written, we are requiring that our clearances meet or exceed NESC + 3'. But in practice, what we all do (or what I think we all do) is to add the 3' (or some other number) to account for uncertainties and inaccuracies so that in the end, we meet NESC clearances. If we extend our clearances by 3', do we need to add another buffer now to account for these (uncertainties)?

Due to uncertainties and inaccuracies in surveying and installation of foundations, structures and conductors, the calculated position of the conductors shall be increased as ~~buffers defined~~ specified in Sections 9.5.1 and 9.~~5~~5.2 ~~shall be added to clearances specified in section 23 of the NESC~~.

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9.5.1 Vertical Clearance Buffer

The vertical clearance buffer shall be 3'-0".

9.5.2 Horizontal Clearance Buffers

The horizontal clearance buffer shall be 2'-0".

Comment [PSG16]: I would assume this does not apply to clearance from conductor to structure components or conductor to conductor at a structure. Ie. Rule 235.

9.6 Electrostatic Clearance

The short circuit current discharge requirements of NESC Rule 232D3(c) shall be met.

9.7 Agricultural Clearances

In ~~land areas that may utilize farm~~ equipment in excess of 14’-6” in heightfarmlands, additional conductor clearances shall be provided in accordance with NESC Table232-1 footnote 26.

9.8 Clearances over Waters of the United States

Clearances over the waters of the United States shall be the larger of the NESC requirements in Rule 232, or the clearance determined by the Army Corps of Engineers, plus the buffer defined in Section 9.5.

9.9 Galloping

9.9.1 General

Lines shall be designed to limit the likelihood that conductor/shield wire galloping will result in a circuit momentary operation. Galloping shall be addressed by one or a combination of the following methods:

- Performing a study which demonstrates that the route traversed by the line is not likely to be prone to the wind/ice conditions attributed to conductor galloping .
- Providing conductor clearances at the structure which produce the in-span conductor clearances defined ~~below~~in Section 9.9.3.
- Install in-span interphase insulators or anti-galloping devices designed to reduce the possibility and/or severity of conductor galloping.
- Install twisted pair conductor.

Comment [PSG17]: A new entrant would benefit from shared prior experience in the area regarding galloping.

Comment [TDP18]: PECO

9.9.2 Galloping Ellipse Calculations

Conductor galloping ellipses shall be developed using ~~either a combination of~~ the A.E. Davison method for single loop galloping and the L.W. Toye method for double loop galloping, or the CIGRE method ~~per~~ as described in Bulletin 322. The following load cases shall be used for galloping calculations for ~~either~~ all stated ~~method~~methods:

Comment [PSG19]: Different galloping models use different assumptions for conductor sag. My understanding is that CIGRE Bulletin 322 uses the sag of the unloaded span at 0ºC. (Section 1, p.2, under Amplitudes).

- 32°F, 0.5” Radial ice, 2 ~~PSF~~ pounds per square foot wind (~~For~~ for determination of Swing Angle)
- 32°F, 0.5” Radial ice, No Wind (For determination of sag and conductor motion ellipses)

Single loop galloping shall be used for spans less than 700 feet. Double loop galloping shall be used for spans of 700 feet or greater or any span where the conductor has dead-end terminations on both ends.

~~Long~~ For long spans over eighteen hundred (1800) feet, ~~shall take into account~~ existing line historical operation. shall be considered. If no data is available, a study shall be performed to determine the proper mitigation methods.

Comment [PSG20]: Would this information be shared? How would we know what the existing line historical operation has been?

9.9.3 Galloping Clearances

~~The conductor clearancec~~Clearances of the calculated galloping ellipses ~~requirements~~ shall meet the requirements of Sections 9.9.3.1 and 9.9.3.2.

9.9.3.1 Single Loop Galloping

The ~~major axes~~postion of the calculated galloping ellipses shall overlap no more than 10%.

Comment [TDP21]: Is it the major axis, or the ellipse itself?

Comment [PSG22]: I am curious if this gives adequate performance. EPRI Orange book and CIGRE 322 recommend a clearance between ellipses.

9.9.3.2 Double Loop Galloping

The calculated positions of the galloping ellipses shall not overlap.

~~When galloping mitigation devices are used, greater overlap of galloping ellipses is permitted.~~Greater overlap in the calculated positions of galloping ellipses is permitted when galloping mitigation devices are used.

9.10 Avian Considerations

The Designated Entity shall comply with all project-specified requirements established by governmental jurisdictions. The guidelines of the Avian Power Line Interaction Committee shall be considered in the design of Transmission Line Facilities.