PJM DESIGNATED ENTITY DESIGN STANDARDS

1.0 PURPOSE

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 Problem Statement and 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 PJM Tariff; and are consistent with current industry standards specified herein, such as NESC, IEEE, ASCE, CIGRE, and ANSI, at the time the PSRD is issued.

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

Comment [TDP1]: LSP1: (Comment applies to both 1.0 and 2.0) A general concern is these standards are applied only to designated entities (e.g. greenfield solutions) and not to transmission owner upgrades. We wouldn't want a situation where a greenfield project is disadvantaged relative to a transmission owner upgrade due to more stringent design standards. We would suggest adding some language to the Purpose/Scope such as:

"The intent of these design standards is to capture standards commonly used by all existing PJM transmission owners. While these minimum design standards do not apply to projects outside of the PJM competitive process, it is expected that all PJM transmission owners design consistent with these standards."

Response: PJM to respond.

Comment [TDP2]: FE1: Can transmission lines be designed with distribution underbuild? (My thoughts – yes, but the minimum design requirements would only pertain to the transmission facilities)

Response: Group discussion required; PJM input needed.

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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 load factors shall be in accordance with NESC Rule 253.

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 year 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.

Comment [TDP3]: LSP2: This section should indicate the following, "The load factors shall be in accordance with NESC Rule 253."

Response: Added.

Comment [TDP4]: LSP3: These sections identify a 100 year return period and Load Factor minimum of 1.0 – these two statements are inconsistent. A 100 year return period would necessitate a minimum Load Factor greater than 1.0. Typical utility practice would be to design to a 50 year return period, which corresponds to the identified Load Factor minimum of 1.0. As such, we would suggest replacing the 100 year return period with a 50 year return period.

Response: The 100 year return period was selected to be consistent with the current practice recommended by the PJM Transmission & Substation Committee (TSS) and the future direction of ASCE (SPP also uses the 100 year MRI). The TSS Transmission Owner Guidelines specifies a wind pressure equal to 25 pounds per square foot (psf) on the wire, and 31.25 psf on the structure. This is slightly greater than loads calculated with a 100 year base return period. The next version of the ASCE MOP 74 will recommend using loads due to a 100 year mean return period and will provide a specific map for such. The current version of MOP provides a conversion from 50 to 100 year return periods using a wind or ice load factor. Although labeled a "load factor" it is not really the same as the load factors mentioned in the rest of the PJM DEDS. Since the DEDS requires loads be calculated in accordance with MOP 74, and because the wind/ice load factors are established therein, no additional statements are required.

Comment [AMS5]: 1)In Section 5.1, are we sure about the 100 year return period? The NESC 2017 Code still refers to ASCE 7-10, which has a 50 year return period. Someone on the NESC committee recently explained to me that the committee does not want to go with a 100 year return period and that is why ASCE 7-16 is not referenced in NESC 2017. In the "Substation subgroup," the 100 year return period may be appropriate. Please correct me if I'm wrong, I'm not as familiar with ASCE 74.

Response: The NESC is a safety code, not a design code, providing requirements for the minimum safe condition. Utilities generally design for higher weather loads for reliability based on experience and local research. See response to LSP3 above.

Comment [TDP6]: FE2: Second line should be 100 year return period. Missing the word 'year'.

Response: Added

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.

Comment [AMS7]: 1" seems heavy. What weather case is this for?
(1" with 2psf or ½ " ice with 4 psf or ¾" ice with 4 psf)

Response: This was a compromise between member utility practice and the TSS guidance of 1.5".

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.

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5.1.5 Unbalanced Longitudinal Load Cases

Except as described in Section 5.1.5.1 and 5.2.2, 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 5.1.5.2 and 5.1.5.3.

Comment [TDP8]: See LSP7.

Except as described in Section 5.1.5.1 and 5.2.2, 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 5.1.5.2 and 5.1.5.3.

5.1.5.1 These unbalanced load cases do not apply to insulators; however, insulators must be designed such that they do not detach from the supporting structure.

5.1.5.2 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 conductor tensions may be reduced by the effects of longitudinal insulator displacement.

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.

5.1.5.3. 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 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.

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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.

Transmission Line Facilities designed for voltages 230kV and less may be designed to resist longitudinal loads simulating a bound stringing block.

5.1.6.2 Climbing and Working Loads

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

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*

Comment [TDP9]: LSP4: This section appears to indicate that the Bound Stringing Block loads are only applied to voltages over 230kV. Was it the intent that this load case be applied to voltages equal to or greater than 230kV?

Response. Yes, the intent was for this provision only to be applied to voltages over 230kV. We will add a sentence stating the "may" requirement for lower voltages for consistency.

Note to sub-group – we are inconsistent in applying the longitudinal criteria w/rt voltage.

Comment [AMS10]: Is this adequate – OSHA – 5000 pounds?

Response: The 250 pounds is for climbing only. Fall protection load is covered by the statement immediately below 5.1.6.

Comment [TDP11]: LSP5: Instead of stating "a minimum of 1.0.", the text should read, "as identified in Section 5.1.1 through 5.1.6."

Response: The intent was that the foundation designer would take the factored loads from Section 5.1, and then apply any additional load factors they deem necessary for foundation design. Suggest we delete the reference to load factors in this section altogether.

Comment [TDP12]: LSP6: Need to add "National Electric Safety Code". The NESC defines material strength factors for transmission line hardware, insulators, foundations, guy wires etc.

Response: Section 3.0 requires general compliance with the NESC. *Should we add?*

This section references "ACI 318 Building Code Requirements for Structural Concrete and Commentary". This should be removed as it is not applicable to typical foundations for transmission lines – see Section 1.4 of ACI 318 (Applicability) and more specifically Section 1.4.6.

Response: Although true, ACI 318 is typically adopted and used in part to design reinforced concrete foundations and anchorages for transmission and substation structures.

We need to discuss how to handle – delete, add exclusions, reference another document?

Comment [TDP13]: FE3:
• Remove IEEE Std. 751 (inactive or withdrawn)
• Add ASCE Manual No. 111 Reliability Based Design of Utility Pole Structures

Response: There is another IEEE publication, P751-Guide for Wood Structures Used for Overhead Electric Transmission Lines. Is anyone familiar? Should we substitute? Regarding ASCE's Reliability Based Design method, is everyone using it?

Comment [AMS14]: Can we add a sentence to account for impact of a slack span on a monopole going into a substation.

Response: Need clarification to respond.

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- *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.

- Voltages 345kV and greater – 1 Outage/100 circuit miles/Year

Comment [TDP15]: LSP7: This section appears to indicate that Section 5.1.5 will not apply if an anti-cascading structure is used every 5 miles. If this is the case, please clarify Section 5.1.5 to address this point (i.e. add a statement in Section 5.1.5 that it does not apply if anti-cascading structure is used every 5 miles in accordance with Section 5.2.2).

Response: Agree; add reference to 5.2.2 in 5.1.5.

It also may be helpful to clarify anti-cascading structure loads. Leaving it up to the bidder to define which weather cases to consider would create a high level of variability in structure performance between bidders.

Response: Sub-group discussion required.

Comment [TDP16]: FE4: This section appears to allow us to ignore the longitudinal requirements of Section 5.1.5 if we use anti-cascading structures. Is this accurate? (My thoughts – I like it, but per previous discussions I didn't think we were heading down this path)

Response: Your interpretation is correct as I recall.

Comment [TDP17]: FE5: Should we include something to the affect that higher voltage lines should cross over lower voltage lines. (My thoughts – we want to use the word "should" for the occasional need to do the opposite when it makes sense)

Response: Group discussion required.

Comment [AMS18]: Is DLC OK with this?

Comment [TDP19]: FE6: We should include what FE calls priority tree rights. These rights allow us to remove trees outside the right-of-way that if dead, dying, or diseased, may endanger the transmission line.

Response: Do we want to discuss vegetation management at all in here? Group discussion required.

Comment [AMS20]: Is DLC OK with this?

Comment [TDP21]: FE7: What method is used for determination?

Response: Design methods were intentionally omitted from this section.

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- 230kV – 2 Outage/100 circuit miles/Year
- 138/115kV – 3 Outage/100 circuit miles/Year
- 69kV – 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 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.

When a proposed transmission line crosses over an existing supply or communication line, the position of the lower wire shall be determined by a straight line between attachment points, unless specific sag/tension information for the lower wires are known. When the sag/tension characteristics of the lower wires are known, the 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 proposed by the Designated Entity for a line design for any of the following maintenance activities:

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

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

9.3 Vertical Clearances

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

9.5 Clearance Buffers

Comment [TDP22]: FE8: FE is changing their buffers to 5'. Any thoughts to increase it here?

Response: Group discussion required.

Due to uncertainties and inaccuracies in surveying and installation of foundations, structures and conductors, the calculated position of the conductors shall be increased as specified in Sections 9.5.1 and 9.5.2 to ensure that NESC requirements are met.

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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" to other obstructions. This buffer does not apply to clearances to the supporting structure.

9.6 Electrostatic Clearance

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

9.7 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.

9.8 Galloping

9.8.1 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:

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- Providing conductor clearances at the structure which produce the in-span conductor clearances defined in Section 9.8.3.
- Install in-span interphase insulators or anti-galloping devices designed to reduce the possibility and/or severity of conductor galloping.
- Install twisted pair conductor.

9.8.2 Galloping Ellipse Calculations

Conductor galloping ellipses shall be developed using the A.E. Davison method for single loop galloping and the L.W. Toye method for double loop galloping, or the CIGRE method as described in Bulletin 322.

9.8.3 Galloping Clearances

Clearances of the calculated galloping ellipses shall meet the requirements of Sections 9.8.3.1 and 9.8.3.2.

9.8.3.1 Single Loop Galloping

The position of the calculated galloping ellipses shall overlap no more than 10%.

9.8.3.2 Double Loop Galloping

The calculated positions of the galloping ellipses shall not overlap.

9.9 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.

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