**PJM DESIGNATED ENTITY DESIGN STANDARDS**

**1.0 PURPOSE**

These design criteria have been established as a minimum design standard to provide a minimum level of robustness such that a new competitively-solicited facility will not introduce a weak point in the system in terms of performance. These minimum design standards do not apply to projects for which solutions are not solicited through the PJM window process.

**2.0 SCOPE**

This document sets forth the 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 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.

**4.0 CONDUCTOR**

**Comment [TDP1]:** Rewritten and eordered based on meeting discussion.

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 all assumptions.

The loss of strength of the conductor shall be limited to 10% of its initial rated breaking strength for an assumed 35 year life. Conductor connectors and accessories shall have strength and thermal capabilities no less than the conductor.

The damaging effects of Aeolian vibration shall be appropriately mitigated during the wire selection and design process. 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 effects of all load cases defined in Section 5.2, including all subsections. The applied loads shall be adjusted by the Load Factors defined in the subsections of Section 5.2, and the material strengths shall be adjusted by the material strength reduction factors specified by the applicable governing industry body referenced in Section 5.3.

**5.1 Definitions**

**Comment [TDP2]:** Review definitions; revise for clarity as needed. – TDP & All

Do we have everything? Do we need everything? - All

Normal, Emergency Ratings

The following definitions apply to this section.

### 5.1.1 Load Factor

A value by which calculated loads are multiplied in order to ~~provide increased structural reliability~~account for undefined variations in the actual applied loads. Synonym: ~~For the purpose of structural design,~~ Overload Capacity Factors as specified by the NESC shall be considered Load Factors.

### 5.1.2 Longitudinal load

~~Forces~~ For tangent structures, forces or pressures acting parallel to the direction of the line. For angle structures, the longitudinal direction is perpendicular to the bisector of the angle of the transmission centerline.

### 5.1.3 Structure, Dead-End and Line Termination

Structures where the phase conductors and shield wires are attached to the structure by use of dead-end insulators and hardware. These structures ~~and where~~have the ability ~~of the structure~~ to resist a condition where all wires are broken on one side under full loading ~~is required or desired under all loading combinations~~.

### 5.1.4 Structure, Strain

A structure where the phase conductors and shield wires are attached to the structure by use of dead-end insulators and hardware ~~but~~ and where ~~the ability of the structure to resist a condition where all wires are broken on one side under full loading is not required or desired.~~ the structure does not have the capacity to resist a condition where all the wires are broken on one side under full loading.

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**Comment [DSG3]:** Proposed change

### 5.1.5 Structure, Suspension

A structure where the ~~phase conductors and shield~~ wires are attached through the use of suspension insulators and hardware or, in the case of the shield wire, with a clamp not capable of resisting the full design tension of the wire.

### 5.1.6 Transmission Line Facilities

Transmission Line Facilities include all supporting structures, insulators, hardware, and foundations. In addition to suspension, strain, dead end and line termination structures, switch structures, overhead-to-underground transition structures, and line transposition structures are considered as Transmission Line Facilities.

**Comment [TDP4]:** Define?

### 5.1.7 Transverse Load

Forces ~~or pressures~~ acting perpendicular to the direction of the line. For angle structures, the transverse direction is parallel to the bisector of the angle of the transmission centerline.

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#### 5.1.8 Wires

Includes all conductors and shield wires.

### 5.2. Design Load Requirements

All Transmission Line Facilities shall be designed to withstand the independent load cases defined in Sections 5.2.1 through 5.2.7. The effects of gravity, wind, ice, wire tension, construction, and maintenance loads shall be included as applicable.

#### 5.2.1. Legislated Loads

**5.2.1.1** 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 these Rules permitting the exclusion of structures less than 60 feet in height shall not apply.

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

#### 5.2.2. Extreme Wind

Transmission Line Facilities shall be designed to resist the wind loads corresponding to a 100 year mean recurrence interval (MRI).

Wind pressures shall be calculated in accordance with the procedures of the latest edition of ASCE Manual of Practice 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.

#### 5.2.3. Concurrent Ice with Wind

Transmission Line Facilities shall be designed to resist the ice loads resulting from freezing rain along with the associated concurrent wind loads corresponding to a 100 year MRI.

Wind pressures shall be calculated in accordance with the procedures of the latest edition of the ASCE Manual of Practice 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.



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All wires shall be assumed intact.

**5.2.4 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 5.2.4.1 through 5.2.4.4.

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.

**5.2.4.1** 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 5.2.4.2, 5.2.4.3, and 5.2.4.4.

**5.2.4.2** Transmission Line Facilities designed for voltages 230kV and greater and constructed in the following states/districts, or portions of the state Pennsylvania 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 coast
- Delaware, within 75 miles of the coast of the Atlantic Ocean
- Maryland, within 75 miles of the coast of the Atlantic Ocean

**5.2.4.3** 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 the 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.

**5.2.4.4** 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 the 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.

**5.2.5. Unbalanced Longitudinal Load Cases**

**Comment [TDP5]:** Provide a comparison of design longitudinal tensions for comparison. – TDP

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Transmission Line Facilities designed for voltages 230kV and greater shall be designed to resist longitudinal loads due to broken wire and differential ice conditions as described in Sections 5.2.5.1 and 5.2.5.2.

Transmission Line Facilities designed for voltages less than 230kV may be designed to resist longitudinal loads due to broken wire and differential ice conditions as described in Sections 5.2.5.1 and 5.2.5.2.

#### 5.2.5.1. 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 phase configurations with more than one sub-conductor of both single and multiple circuit structures, a minimum of one sub-conductor or one ground wire shall be considered broken in each load case. The conductor bundle with the sub-conductor(s) broken shall be considered individually to ensure the maximum loading effect is determined for each component.

The minimum environmental load condition shall be 0.5 inches of ice, 40 mph wind, and 32°F. 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.

#### 5.2.5.2. 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 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.

### 5.2.6. Construction and Maintenance Loads

Transmission Line Facilities shall be designed to meet all applicable OSHA requirements related to climbing and fall protection, and the provisions of this section.

#### 5.2.6.1 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. Apply 2 pounds per square foot of wind loading and no ice at a temperature of 30°F. The Load Factor shall be a minimum of 1.5.

**5.2.6.2 Climbing and Working Loads**

Structures shall be designed to support a point load of 350 pounds at all areas to accommodate construction or maintenance activities.

**5.2.7. Foundation Loading**

Foundation reactions shall be determined from the load cases presented in Section 5.2. Load Factors shall be a minimum of 1.0.

**5.3 Strength Requirements**

Transmission Line facilities shall be designed for sufficient strength as specified in Sections 5.3.1 through 5.3.3.

**5.3.1 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*

**5.3.2 Line Cascading Mitigation**

Transmission line failures that cascade beyond the original structure failure must be avoided. The line shall be designed so that a cascading event does not result in failure or severe damage to structures extending beyond a distance of "X" miles from the point of

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origin. Preventative measures may include, but are not limited to, routine placement of deadend structures, longitudinal guying, etc., along the alignment. Documentation shall be provided upon request by the line designer proving the design meets these requirements. Line restoration strategy should be considered when selecting the appropriate interval for line cascading mitigation.

To avoid cascading failures, structures shall be designed to withstand the unbalanced longitudinal load cases of Section 5.2.5, or an anti-cascading structure shall be placed every 5 miles.

**5.3.3 Geotechnical Requirements**

A geotechnical investigation ~~study~~ shall determine the soil and rock properties for the foundation designs.~~be the basis of the final foundation design parameters.~~ The geotechnical study shall consist of test borings and situ tests to provide a set of boring logs that contain information the subsurface properties at each boring site.

**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 TV and Radio interference. To correct for voltage imbalance, the phases may be transposed.

~~The Designated Entity shall determine by calculation the levels of audible noise and EMF values at the edge of ROW. These calculated values shall not exceed those required by state and local authorities.~~The estimated levels of audible noise and EMF values shall not exceed those required by state or local authorities. These estimated values shall be determined by calculations specific to the proposed transmission facility.

**7.0 RIGHT-OF-WAY**

~~At a minimum, sufficient r~~Rights of way ~~width~~ shall be ~~provided so~~proportioned so that NESC horizontal clearances to buildings ~~(plus a three foot buffer?)~~ are maintained ~~to~~ at the edges. Consideration shall also be given to existing and future use of the area beyond their boundaries. Widths shall be calculated with the wires ~~of the right of way, and to adjacent power lines when they exist. This should be calculated with conductors at rest (no wind), final sag, and at the maximum operating temperature; and also with the conductors~~ displaced ~~due to~~from rest by a 6 psf wind at 60°F with no ice, at final sag ~~condition~~. Deflection of flexible structures and insulator swing shall ~~also~~ be ~~included in this calculation~~considered where appropriate. ~~Other considerations shall be made for vegetation management, maintenance, future development and anything else that may impact the long term reliability, maintenance and safe operation of the line.~~ The design entity shall ensure that the right of way width meets their Vegetation Management clearance guidelines to ensure compliance with NERC FAC-003 requirements.

**Comment [TDP6]:** The AESO (Alberta ISO) suggests that if tangents have a defined (and they do, albeit more stringent than ours) longitudinal strength, then anti-cascading structures are required.. See alternative wording below.

**Comment [TDP7]:** We don't have this requirement elsewhere. If we need it, suggest making it universal and placing in Section 3.

**Comment [TDP8]:** This should be part of the PSRD; suggest striking.

**Comment [TDP9]:** Proposed alternative wording.

Group accepted this proposal at the last meeting. Checking w/ Drew for his thoughts.

**Comment [TDP10]:** Do we need more definition?

**Comment [TDP11]:** Proposed alternate language.

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**Comment [TDP12]:** This is probably just guessing.

~~EMF and AN at edge of ROW to meet state and local requirements.~~

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

**8.0 INSULATION, LIGHTNING PERFORMANCE, & GROUNDING**

*The following is proposed text from Bob:*

In order to ensure safe and reliable operation of the line(s) under normal operation and during surge events such as switching or lightning, the DE shall specify insulation levels that meet or exceed the thresholds provided in Table 1 for leakage distance, power frequency wet withstand and critical impulse flashover withstand voltage levels. Grounding *target* levels for individual structures are also provided in Table 1 and shall be measured on each individual structure prior to the installation of any overhead conductors or wires, or measured using techniques to eliminate their contributions. A minimum of one shield wire is required above each circuit and additional may be required to meet the shielding angle requirements in Table 1. Shielding angle shall be maintained under conductor and shield wire conditions of 60F and swing angles from at-rest positions through 6psf of wind, at final loaded position.

The use of transmission line surge arresters to improve lightning performance shall be allowed only after exhausting other economical options such as additional shielding, improved grounding, or additional insulation. Surge arresters shall be applied to ensure reliable normal operation of the line in the event of surge arrester electrical or mechanical failure.

*The following is proposed modifications to the text by Dave Parrish:*

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. ~~Grounding target levels for individual structures shall be provided by the Designated Entity and shall be measured on each individual structure.~~ Shielding, grounding and footing ground resistance shall be designed by using TFLASH or equivalent software program to verify that the line design will result in the desired lightning performance. The grounding measurements shall be made using meters and procedures appropriate for the conditions. All meters must be calibrated within 12 months of their use.

Target Footing resistance shall be 25 ohms for voltages 230 kV and below and 15 ohms for voltages above 230 kV.

Target shield angles shall be 25° for lines operated at 230 kV and 15° for line operated above 230 kV.

~~A~~ A minimum shielding angle of 30° or less is required~~shall be maintained~~.

Conductors and shield tensions shall be assumed at final sag conditions, and at 60° F and no wind. The~~is~~ shielding angle shall be measured at the structure.

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.

*The following is the text from the SPP MDS:*

**Comment [DSG13]:** Should we remove the previous PJM criteria??

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Insulation, grounding, and shielding of the transmission system (line and station) shall be coordinated between the Designated Transmission Owner and the Transmission Owner(s) to which the project interconnects to ensure acceptable facility performance.

All metal transmission line structures, and all metal parts on wood and concrete structures shall be grounded. Overhead shield wires shall also be grounded, or a low impulse flashover path to ground shall be provided. Grounding requirements shall be in accordance with the NESC.

## 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 the line under design is crossing over an existing supply or communication line, the lower conductors' position shall be determined by a straight line between conductor attachment points unless specific sag/tension information for the lower conductors/cables are known. When the sag/tension characteristics of the lower conductors/cables are known, the conductor 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
- Hot stick maintenance for the specified line components
- Live line maintenance for the specified line components utilizing specified lift equipment
- Helicopter live line maintenance for the specified line components utilizing the specified helicopter

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

### 9.3 Vertical Clearances

The vertical conductor clearances of Section 23 of the NESC shall be maintained with the conductors under design at the NESC stated conditions unless modified in Sections ~~9.3.1~~9.5 ~~through 9.3.3~~. All terrain points under the conductors shall be considered vehicle-accessible.

9.4 Horizontal Clearances

**Comment [DSG14]:** Added Horizontal clearances to ensure we comply with blowout concerns.

The horizontal conductor clearances of Section 23 of the NESC shall be maintained with the conductors under design at the NESC stated conditions unless modified in Sections 9.5.

9.5 Margin of Safety

Due to uncertainties and inaccuracies in surveying and installation of foundations, structures and conductors an additional "Margin of safety" clearance value shall be added to clearance specified in section 23 of the NESC.

Comment [DSG15]: Updated Tolerances to Margin of Safety. Margin of Safety includes both vertical and horizontal requirements.
Added clearance margins for new structures and existing structures (reconductoring)

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**9.5.13.2 Vertical Clearance Margin**

**The vertical safety margin for new construction shall be 3'-0"**

**The vertical safety margin for reconductoring on exist. strutures shall be 1'-0"**

**9.5.2 Horizontal Clearance Margin**

**The horizontal safety margin for new construction is 2'-0"**

**The horizontal safety margin for reconductoring on exist. structures is 0'-6"**

**~~Tolerances~~**

~~The calculated position of the lowest conductors shall be 3 feet higher than the clearances required by NESC Table 232-1.~~

**9.35.3 Electrostatic Clearance**

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

**9.35.4 Agricultural Clearances**

In land areas that may utilize farm, additional conductor clearances shall be provided in accordance with NESC Table232-1 footnote 26.

**9.4 6 Clearances over Waters of the United States**

Clearances over the waters of the United States shall be the larger of ~~based, at a minimum, on~~ the NESC requirements in Rule 232, plus a 3 foot buffer or the clearance determined by the~~. In the event that the~~ Army Corps of Engineers (ACOE) ~~determines higher clearances are required, the ACOE requirements shall be held,~~ plus a 3 foot buffer.

Comment [TDP16]: Do they typically? If they are larger, why not the larger of NESC + 3 or the ACOE clearance.

**9.5 7 Galloping**

**9.57.1 General**

Lines shall be designed to limit the likelihood that conductor/shield wire galloping will result in a circuit 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
- 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.~~5~~7.2 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 Bulletin 322. The following load cases shall be used for galloping calculations for either stated method:

- 32°F, 0.5” Radial ice, 2 PSF wind (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 spans over eighteen hundred (1800) feet shall take into account existing line historical operation. If no data is available a study shall be performed to determine the proper mitigation methods.

**9.~~5~~7.3 Galloping Clearances**

The conductor clearance requirements shall meet the requirements of Sections 9.~~5~~7.3.1 and 9.~~5~~7.3.2.

9.~~5~~7.3.1 Single Loop Galloping

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

9.~~5~~7.3.2 Double Loop Galloping

The calculated positions of the galloping ellipses shall not overlap.

**9.~~6~~ 8 Avian Considerations**

The Designated Entity shall comply with all project-specified requirements established by federal, state, and local authorities. The guidelines of the Avian Power Line Interaction Committee shall be considered in the design of Transmission Line Facilities.

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