Designated Entity Design Standards Task Force

Minimum Required Standards

Developed by the DEDSTF

Version 2.0.3

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1.0) Introduction

These requirements are intended to be the minimum standards to which any entity shall design and build to, when interconnecting to PJM facilities. Transmission Owners ("TO's") traditionally have additional technical interconnection requirements that may be greater than the requirements outlined in this document. This set of minimum design standards was developed by the Designated Entity Design Standards Task Force to assure a minimum level of robustness is provided such that the new competitively-solicited facilities would not introduce a weak point in the system in terms of performance. The task force consists of PJM Transmission Owners, PJM Transmission Developers and other PJM Stakeholders.

2.0) Applicability

The minimum design standards included in this document are required for all competitively solicited projects which are required to sign the Designated Entity Agreement. Adherence to these minimum design standards will be a consideration in the RTEP Proposal Window selection process.

In addition to the requirements included in this document, designated entities must act in accordance with all PJM and industry requirements as described in Section 4.0 of the Designated Entity Agreement. While this document describes details, criteria and philosophy, it is also understood that all other applicable requirements of other standards shall be followed at a minimum, including, but not limited to IEEE, FERC, NERC, NESC, NFPA, IBC, etc.

Transmission Lines Minimum Required Standards

3.0) Transmission Lines Minimum Required Standards - Overhead Lines

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 the governmental authority having jurisdiction, including but not limited to environmental and FAA regulations. 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.

3.1 CONDUCTOR

The Designated Entity shall determine normal and emergency ratings for both summer and winter seasons using an appropriate facility rating methodology.

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.

3.2 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 3.2.1, including all subsections. The applied loads shall be adjusted by the Load Factors defined in the subsections of Section 3.2.1, and the material strengths shall be adjusted by the material strength reduction factors specified by the applicable governing industry publications referenced in Section 3.2.2.

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

3.2.1 Design Load Requirements

All Transmission Line Facilities shall be designed to withstand the independent load cases defined in Sections 3.2.1.1 through 3.2.1.7. The effects of gravity, wind, ice, wire tension, construction, and maintenance loads shall be included as applicable.

3.2.1.1 Legislated Loads

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.
- The Designated Entity shall identify and design to all additional legislated requirements as adopted by the governmental authority having jurisdiction.

3.2.1.2 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.

3.2.1.3 Ice with Concurrent 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.

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.

3.2.1.4 Heavy Ice

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

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.

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 below.

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

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.

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.

3.2.1.5 Unbalanced Longitudinal Load Cases

Except as described below, in the Unbalanced Load Cases and Line Cascading Mitigation sections, 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 below in the Broken Wire Loading and Differential Ice Loading sections.

Except as described below, in the Unbalanced Load Cases and Line Cascading Mitigation sections, 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 below in the Broken Wire Loading and Differential Ice Loading sections.

Unbalanced Load Cases

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

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.

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.

3.2.1.6 Construction and Maintenance Loads

Transmission Line Facilities shall be designed to facilitate construction and maintenance activities as defined below.

Bound Stringing Block

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

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

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.

Fall Protection

Transmission Line Facilities shall be designed to facilitate compliance with OSHA requirements related to fall protection.

3.2.1.7. Foundation Loading

Foundation reactions shall be determined from the load cases presented in Section 3.2.1.

3.2.2 Strength Requirements

Transmission Line facilities shall meet the strength requirements specified in Sections 3.2.2.1 through 3.2.2.4.

3.2.2.1 Strength Design Standards & Guides

Structures and foundations shall be designed to the requirements of the applicable industry accepted specifications and guidelines including, but limited to:

- 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
- National Electric Safety Code C2
- ACI 318 Building Code Requirements for Structural Concrete and Commentary
- Exception: The ultimate compressive concrete strength shall not be less than 3500 pounds/square inch.

3.2.2.2 Line Cascading Mitigation

To avoid cascading failures, structures shall be designed to withstand the unbalanced longitudinal load cases of Section 3.2.1.5, or an anti-cascading structure with full dead end load capability shall be placed every 5 miles.

3.2.2.3 Substation Structure Strength

Where Transmission Line Facilities terminate in substations owned by others, the Designated Entity shall coordinate with these owners to ensure adequate strength is provided for each station line terminal structure.

3.2.2.4 Geotechnical Requirements

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

3.3 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 the governmental authority having jurisdiction. These estimated values shall be determined by calculations specific to the proposed transmission facility.

3.4 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.

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

3.5 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
- 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.

3.6 CLEARANCES

3.6.1 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.

3.6.2 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.

3.6.3 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 3.6.5 shall be applied.

3.6.4 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 3.6.5 shall be applied.

3.6.5 Clearance Buffers

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 3.6.5.1 and 3.6.5.2 to ensure that NESC requirements are met.

3.6.5.1 Vertical Clearance Buffer

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

3.6.5.2 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.

3.6.6 Electrostatic Clearance

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

3.6.7 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 3.6.5.

3.6.8 Galloping

3.6.8.1 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:

- Providing conductor clearances at the structure which produce the in-span conductor clearances defined in Section 3.6.8.3.
- Install in-span interphase insulators or anti-galloping devices designed to reduce the possibility and/or severity of conductor galloping.
- Install twisted pair conductor.

3.6.8.2 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.

3.6.8.3 Galloping Clearances

Clearances of the calculated galloping ellipses shall meet the following requirements:

Single Loop Galloping

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

Double Loop Galloping

The calculated positions of the galloping ellipses shall not overlap.

3.6.9 Avian Considerations

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

3.7 Underground Lines

3.7.0 GENERAL REQUIREMENTS

3.7.0.1 Underground transmission lines 69 kV and above shall be solid dielectric, self-contained fluid filled, or pipe type cables. Definitions for underground design terminology can be found in the "PJM Underground & Submarine Transmission Cable Rating Methodology Guidelines.

3.7.0.2 The best practices and guidelines, along with applicable latest industry standards and procedures outlined in the EPRI Underground Transmission Systems Reference Book, shall be followed.

3.7.0.3 Shunt reactive compensation shall be considered and provided when system conditions dictate. The need for shunt reactive compensation will depend on the overall cable capacitance and the system source impedance under all cable system operating conditions.

3.7.0.4 Surge arresters shall be considered at all termination locations to protect the underground cable system from transients caused by lightning or switching. However, a switching surge analysis should be performed for cable insulation coordination and protection.

3.7.0.5 Parallel spare conduits and/or spare pipes shall be considered for installations at major crossings including water crossings and for long length inaccessible locations.

3.7.0.6 The cable system shall be designed in accordance with, but not be limited to, the latest edition of the following industry standards, as applicable.

<u>Pipe-Type Cable Systems</u>

- Association of Edison Illuminating Companies AEIC CS2, "Specifications for Impregnated Paper and Laminated Paper Polypropylene Insulated High Pressure Pipe Type Cable" when specifying pipe type cable (includes HPFF and HPGF cable types).

- Association of Edison Illuminating Companies AEIC CS4, “Specifications for Impregnated Paper Insulated Low and Medium Pressure Self Contained Liquid Filled Cable” when specifying SCFF cable. Note that although paper-polypropylene-paper (PPP) insulation can be used on SCFF cables, the AEIC Specification does not include PPP insulation in this specification. This is because pipe type systems make up the majority of transmission applications in the US and SCFF designs using PPP have not been installed to date.

- ASTM A523, “Standard for Plain End Seamless and Electric-Resistance-Welded Steel Pipe for High Pressure Pipe Type Cable Circuits.”

- ASTM A312/A312M, “Standard Specification for Seamless, Welded and Heavily Cold Worked Austenitic Stainless Steel Pipes.”

- AEIC CS31, “Specification for Electrically Insulating Pipe Filling Liquids for High-Pressure Pipe-Type Cable.”

- NACE Standard SP0169, “Control of External Corrosion on Underground or Submerged Metallic Piping Systems.”

Solid Dielectric Cable Systems

- Association of Edison Illuminating Companies AEIC CS9, “Specification for Extruded Insulation Power Cables and their Accessories Rated above 46 kV through 345 kV AC” when specifying solid dielectric cable.

- IEEE 575, “Guide for the Application of Sheath-Bonding Methods for Single-Conductor Cables and the Calculation of Induced Voltages and Currents in the Cable Sheaths.”

- IEC 62067, “Power Cable with Extruded Insulation and Their Accessories for Rated Voltages Above 150 kV up to 500 kV – Test methods and Requirements”

- ANSI/ICEA S-108-720, “Standard for Extruded Insulation Power Cables Rated Above 46 through 345 kV.”

- IEC 60840, “Power Cables with extruded insulation and their accessories for rated voltages above 30 kV (Um = 36 kV) up to 150 kV (Um = 170 kV) –Test methods and requirements.”

- AEIC CG13-11, “Guide for Testing Moisture Impervious Barriers Made of Laminated Foil Bonded to the Jacket of XLPE Transmission Cables.”

All Cable Systems

- IEEE Std. 404, “Standard for Extruded & Laminated Dielectric Shielded Cable Joints Rated 2.5 kV – 500 kV when specifying cable systems.

- IEEE Std. 48, "Standard Test Procedures and Requirements for Alternating-Current Cable Terminations 2.5 kV – 765 kV when specifying cable systems.

- IEEE Standard 442, "IEEE Guide for Soil Thermal Resistivity Measurements."

DESIGN PARAMETERS

3.7.1 ROUTING

3.7.1.1 The following shall be considered when determining the optimal line route:

A. Length of route
B. Environmentally sensitive areas
C. Archeological or historical areas
D. Type of existing land use (easements, urban, suburban, rural)
E. Ability to obtain ownership or easement rights
F. Maintenance access
G. Proximity to obstacles (rivers, major highways, railroads)
H. Traffic control
I. Adjacent existing underground utilities
J. Existing above and below ground facilities and their required horizontal and vertical separations
K. Jack & bore or Horizontal Directional Drilling (HDD) options and potential frac-out releases
L. Changes in elevation
M. Sources of thermal energy such as other circuits, steam mains
N. Permitting timelines
O. Soil types
P. Soil thermal resistivity
Q. Pulling calculations and maximum reel lengths
R. Manhole and splice locations
S. Feasibility of construction

3.7.2 Ampacity Overview

3.7.2.1 The Designated Entity shall determine normal and emergency ratings for both summer and winter seasons using an appropriate facility rating methodology.

3.7.2.2 Cable ampacity calculations shall be performed for two conditions, normal (steady-state) and emergency, and shall consider the following factors:

A. Cable Insulation
B. Load factor
C. Conductor size, materials, and construction
D. Dielectric losses

E. Mutual heating effect of other heat sources like existing and future cables, ducts, steam mains, or other underground facilities that have an effect on the rating of the cable
F. Ambient earth temperature
G. Depth of burial
H. Type of surrounding environment (soil, duct bank, concrete, grout) and their thermal characteristics
I. Pipe size or conduit size and spacing

3.7.2.3 A route thermal survey and laboratory testing shall be performed to obtain the native soil thermal resistivity and ambient soil temperatures at expected cable installation depths along the route for use in the rating calculations to select the conductor size.

3.7.2.4. Corrective thermal backfill materials shall be considered for transmission cable systems not placed in a duct bank, or when needed to meet or increase ampacity. These can be compacted engineered graded sand, compacted granular backfill, or a fluidized thermal backfill.

3.7.2.5. A comprehensive review of the cable's installation data must be performed in order to determine its final design rating. Installation factors that affect cable ratings include ambient earth temperature, thermal resistivity of existing and placed backfill, spacing between other sources of heat, burial depth, etc.

Final ampacity calculations shall be performed based on the installed line conditions. The original design parameters used for the cable ampacity calculations shall be validated by field testing and using as-builts of the installation. In-situ soils, placed concrete and engineered backfill shall be tested to determine the as-built thermal resistivities for use in performing the final ampacity calculations.

3.7.2.6 For more information concerning how cable rating calculations are implemented in the operation of transmission lines, see PJM Manual 3: Transmission Operations (Section 2 Thermal Operating Guidelines).

3.7.3 Pipe Type Cable Considerations

3.7.3.1 Pipe Type Cables Systems shall be either High Pressure Fluid Filled (HPFF) or High Pressure Gas Filled (HPGF) systems. Pipe Type Cables Systems shall have all three insulated cable phases installed in a common steel pipe. The cables shall transition to three smaller individual stainless steel pipes to permit termination of the cable. Only one insulated cable is installed in the smaller, stainless steel pipe.

3.7.3.2 Coating systems shall be applied to both the inside and outside of the steel pipes to provide primary protection against corrosion prior to and after installation. Coatings shall be mastic, polyethylene, or fusion bonded epoxy with an epoxy-concrete.

3.7.3.3 The design shall include a cathodic protection system, that when installed with the coating system will protect the integrity of the steel pipes and minimize leaks. The system shall be either 1) a passive system where galvanic anodes are installed along the pipe route (if a holiday occurs in the pipe coating, the anode bags provide the sacrificial ions instead of the pipe), or 2) an impressed current system where an alternating current source powers a rectifier supplying the ions from an array of anode bags usually located at one end of the pipe(s).

3.7.3.4 Pipe type cables shall be insulated with kraft paper or laminated paper polypropylene (LPP) tape. Other tapes shall be used for shielding, segmental insulation, moisture barriers, binder tapes and outer shielding tapes. Two “D” shaped skid wires shall be spiral wrapped around the final insulated cable to reducing pulling friction while protecting the cable insulation during installation. Skid wire material shall be specified due to the different coefficient of friction (COF) value of the material.

3.7.3.5 Insulating fluids shall be added to the pipe after cable installation for HPFF cable systems. Insulation fluids shall meet the requirements of the HPFF circuit, such as fluid circulation and/or forced cooling if additional power transfer is required of the HPFF cable system.
Route elevation, pipe size, cable size, and circuit length shall be taken into consideration for hydraulic calculations in determining the rated fluid pressure on the cable system and pressure settings for the relief valves in the pressurization plant.
The fluid in the HPFF system shall be at rated pressure prior to energizing the cables. A hydraulic soak period shall be implemented to bring or return the HPFF system to rated pressure. The fluid shall be at rated pressure for 24 hours before testing or energizing the cable.

3.7.3.6 Straight, anchor, stop, semi-stop, and trifurcating joints shall be designed to connect the cable sections and provide other features for the cable system as needed. Insulation over the splices must meet the same performance standard as the cable insulation and control the electrical stress of the splice. All three cable phases shall be spliced at the same location. The design shall take into account that the splices are encased in a carbon steel telescoping pipe of multiple sections. Design shall consider that splices be installed in manholes for future access.
All phase cables shall be supported to prevent thermal mechanical bending (TMB.) Specialized anchor and skid joints shall be used for steep inclines and drastic changes in elevation to minimize thermal mechanical movement. Restraint locations and design and placement methodology shall follow good engineering practices.

3.7.3.7 For HPFF and HPGF pipe systems, terminations shall be designed and installed to seal the insulating fluid or insulating gas from the environment.
The design shall ensure that the termination is sized to the cable and meets the operating pressures and rating requirements of the cable system for anticipated conditions. The termination’s insulation creepage distance shall be selected based upon the operating environment. Cable terminations shall be selected based on hydraulic calculations for the operating pressure per IEEE Std. 48 for class 1C terminations.
The termination mounting plate and riser pipes shall be test fit prior to welding. Proper fit is required for final weld of the mounting plate’s tail piece pipe to the riser pipe and ensures the termination will be plumb.
The Designated Entity shall ensure coordination between GIS manufacturer, termination manufacturer, cable installation contractor, and GIS contractor for a successful GIS termination installation.

3.7.3.8 A Pressurization/pumping plant shall be designed to pressurize the dielectric fluid in HPFF cable systems for all loading conditions. The nominal operating pressure shall be 200 PSI. The plant shall be designed and built for the specific circuit parameters such as pipe size, cable size, length of the cable circuits and any circulation requirements. Additional pressurization/pumping plants may be required for long underground cables to meet the reliability requirements of the owner, and if there are multiple hydraulic sections in the cable circuit. Environmental concerns shall be considered in the siting and foundation design for dielectric fluid containment.

Pressurization/pumping plants shall have plant alarms and control systems to ensure pressurization of the cable system. Alarm settings shall be based upon criticality and the response time to the alarm. These alarms shall be designed and utilized to minimize the loss of dielectric fluids. Improper operation and abnormal conditions shall be reported to the system or local control center for immediate corrective action. Leak detection systems may be installed in the pressurization plant for HPFF cable systems if the Designated Entity requires it for environmentally sensitive areas. Leak detection compares the predicted fluid entering a cable system versus actual fluid entering the cable system. This can be alarmed before the leak grows larger.

Pressurization/pumping plants shall operate by a programmable logic controller (PLC) that offer information on the circuit(s) and the various systems inside the pressurization plant. These various systems shall be alarmed. A PLC shall provide remote access to the controls in the pressurization plant for a faster response time to an alarm.

Two independent sources of power to the pressurization plant are required with an automatic transfer of power to ensure continuous AC feed to the pressurization plant. The second power source can be a backup generator, dedicated off site power line, or an alternate bus source or nitrogen driven pumps.

3.7.3.9 A crossover cabinet shall be installed on the opposite end of the pipe type cable system from the pressurization plant. This cabinet shall house an electric valve that will tie the cable pipes together and open when necessary (usually when low pressure develops on one pipe) to hydraulically normalize the pressure on the pipe experiencing low pressure. This valve should be alarmed notifying the control center it has opened for an abnormal reason.

3.7.3.10 Testing

Testing pipe type transmission cables and accessories is required to qualify cable and cable components for design, installation verification, qualification/acceptance and operations and maintenance purposes. Test standards and procedures developed for pipe-type cable by organizations such as the Association of Edison Illuminating Companies (AEIC), the Insulated Conductors Committee (ICC) of the IEEE, the International Electrotechnical Commission (IEC), and the Insulated Cable Engineers Association (ICEA) shall be applied to the pipe cable system.

Note: The EPRI Green Book dedicates an entire chapter to cable testing which describes the principles of cable and accessory testing, summarizes the applicable standards, guides, and procedures that are commonly accepted by the cable industry. It addresses specific test procedures, laboratories, equipment for ac, impulse, dc, thermomechanical tests, and describes diagnostic procedures employed in the laboratory and in the field.

3.7.4 Solid Dielectric Cable Considerations

3.7.4.1 Extruded dielectric cable systems shall be insulated with ethylene-propylene rubber (EPR) for installations with voltages up to and including 138 kV, or with cross-linked polyethylene (XLPE) insulation for installations 69 kV and above.

3.7.4.2 A metallic moisture barrier or sheath, such as a lead sheath, corrugated copper or aluminum sheath, or copper or aluminum foil laminate, is required to prevent moisture from entering the cable.

3.7.4.3 The cable shall have a durable, moisture-resistant thermoplastic compound for use as the jacket to provide mechanical and corrosion protection. The cable shall be designed with an electrically conducting coating on the outside of the jacket that is suitable for jacket integrity tests, and that will be electrically continuous after the cable is installed. This coating shall be a graphite varnish coating or a semi-conducting extruded layer.

3.7.4.4 The metallic shield and sheath shall be bonded to the local ground, using either multipoint bonding, single point bonding or cross bonding.

3.7.4.5 The cable sheath, bonding cables, and ground continuity conductors shall be designed for the expected fault current and clearing time. The cable system shall have grounding link boxes and sheath overvoltage protector link boxes for connecting the cable sheath to the substation ground grid and to facilitate performing jacket integrity tests.

3.7.4.6 The design shall consider the time to repair and return to service for direct burial vs. a conduit system.

3.7.4.7 Link boxes shall be constructed of type 316 stainless steel or other non-corroding metal. Link boxes shall have bolted, removable copper or brass links capable to carry the fault current. The link boxes shall be weather-tight. For manhole installations, the link box shall withstand submerged water depths and harsh manhole environments. An IP 68 rating is required.

3.7.4.8 For single point grounded cable systems, a ground continuity conductor shall be provided for the line for proper fault current to flow. The quantity and size of the ground continuity conductors shall be calculated per IEEE 575. For single point grounded cable systems, a link box with a sheath voltage limiter is required to protect the cable jacket from damage during a fault. For single point grounding, the voltage rise at the open end of the shield shall be limited to 150V under normal conditions (both normal and emergency ratings) and not under faulted conditions due to lightning or switching situations.

3.7.4.9 For cross bonded grounding, link boxes shall be installed at the transposition points with sheath voltage limiters to protect the cable jacket from damage during a fault.

3.7.4.10 Sheath voltage limiters shall be adequately sized for nominal and transient voltages that occur during fault conditions.

3.7.4.11 Splices shall be of the same insulation class as specified for the cable. The current ratings of the splices shall be as a minimum the current rating of the cable for which the cable splice is designed. The splice construction shall be water tight

3.7.4.12 Terminations shall be sized and rated for the cable system. The terminations and component parts shall be Class 1 terminations as defined in IEEE Standard 48. The proposed terminations shall be supplied with means to maintain the hermetic sealing of the cable system where the metallic cable sheath is connected to the termination. Standoff insulators capable of withstanding 20 kV dc for one minute shall be supplied with each cable termination.

3.7.4.13 The cable system shall be designed to prevent damage to the cable during installation based on the manufacturer specified sidewall pressure and cable bending radius limits.

3.7.4.14 A manhole racking and clamping system shall be designed to withstand cable forces during normal operations and fault conditions. All racking hardware shall be made with corrosion resistant material to withstand the harsh manhole environment.

3.7.4.15 The cable shall be supported at the termination support structures by clamps and other accessories specifically designed for the cable and its diameter. The cable clamps and bolts shall be designed to not corrode in the specified project environment. For long unsupported vertical inclines, the design shall include a cable support system.

3.7.4.16 A jacket integrity test shall be performed on each section of cable prior to and after installation to ensure that the cable jacket has not been damaged during shipping or after cable pulling. The cable jacket shall withstand a dc voltage of 10 kV for 1 minute.

3.7.4.17 Testing solid dielectric transmission cables and accessories is required to qualify cable and cable components for design and qualification/acceptance. Test standards and procedures developed by organizations such as the Association of Edison Illuminating Companies (AEIC), the Insulated Conductors Committee (ICC) of the IEEE, the International Electrotechnical Commission (IEC), and the Insulated Cable Engineers Association (ICEA) shall be applied to the cable testing.

3.7.4.18 Cable voltage tests shall be performed on the terminated cables after installation. The cables shall pass these tests when conducted in accordance with the latest applicable IEEE, AEIC, IEC and CIGRE specifications and guidelines.

3.7.4.19 An AC soak test at no load and full voltage for a period of 24 hours shall be performed on the installed cable system.

3.7.4.20 A one hour AC voltage withstand test at 1.7 x rated line-to-ground voltage shall be performed per IEC 62067 and IEC 60840 for all cable systems 69 kV and above. Partial discharge detection measurements shall be performed on all accessories continuously during the voltage test.

Substations Minimum Required Standards

4.0) Substations Minimum Required Standards

4.1 GENERAL DESIGN CRITERIA:

These design criteria have been established to assure acceptable reliability of the Bulk transmission system facilities. These set forth the service conditions, and establish insulation levels for lines and substations, and short circuit levels for substation equipment. Specific component requirements are listed in their own sections (in addition to NESC the IEC 61936 provides a solid reference).

Environmental Conditions:

Ambient Temperature	-30(-40)°C to +40°C (-40°C may be required for areas of low temperature weather)
Wind	- ASCE MOP 113 - NESC - ASCE 7
Ice	- ASCE MOP 113 - NESC - ASCE 7
Seismic Load	- ASCE MOP 113 seismic map for site specific requirements, Site Specific Soil Class. - Equipment qualification per IEEE 693
Line Load	- NESC - ASCE MOP 113
Flood Plain	Structure ground line above 100yr flood where possible

765 kV Substations Electrical

Line Terminal and Equipment Continuous Current	3,000A minimum, but designed to application
3 second current (short circuit)	50kA minimum, but designed to application
Nominal/ Max Operating Voltage	765kV / 800kV
Lightning Impulse Withstand Voltage w/o line entrance arresters	Dependent on outcome of insulation coordination study

Lightning Impulse Withstand Voltage with line entrance arresters	2050kV
Switching Impulse withstand level (3σ)	1700kV
Typical Surge Arrester	Size based upon Insulation Coordination
Circuit Breaker line closing switching surge factor	2.2 depending on Switching Surge Studies
System Grounding	Effectively Grounded Neutral (always)

500kV Substations Electrical

Line Terminal and Equipment Continuous Current	3,000A minimum, but designed to application
3 second current (short circuit)	40kA minimum, but designed to application
Nominal/ Max Operating Voltage	500kV / 550kV
Lightning Impulse Withstand Voltage w/o line entrance arresters	1,800 kV 1705 (Chopped Wave)
Lightning Impulse Withstand Voltage with line entrance arresters	1550 kV
Switching Impulse withstand level (2σ)	1050 kV
Typical Surge Arrester	Size based upon Insulation Coordination
Circuit Breaker line closing switching surge factor	2.2 depending on Switching Surge Studies
System Grounding	Effectively Grounded Neutral (always)

345kV Substations Electrical

Line Terminal and Equipment Continuous Current	2,000A minimum, but designed to application
3 second current (short circuit)	40kA minimum, but designed to application
Nominal/ Max Operating Voltage	345kV / 362kV

Lightning Impulse Withstand Voltage w/o line entrance arresters	1300 kV
Lightning Impulse Withstand Voltage With line entrance arresters	1050 kV
Switching Impulse withstand level (2σ)	750kV
Typical Surge Arrester	Size based upon Insulation Coordination
Circuit Breaker line closing switching surge factor	2.2 depending on Switching Surge Studies
System Grounding	Effectively Grounded Neutral (always)

230kV Substation Electrical

Line Terminal & Equipment Continuous Current	2,000A minimum, but designed to application
3 second short circuit current	40kA minimum, but designed to application
Nominal/ Max Operating Voltage	230kV / 242kV
Lightning Impulse Withstand Voltage	900kV BIL
Typical Surge Arrester	Size based upon Insulation Coordination
System Grounding	Effectively Grounded Neutral (always)

138kV Substation Electrical

Line Terminal & Equipment Continuous Current	2,000A minimum, but designed to application
3 second short circuit current	40kA minimum, but designed to application
Nominal/ Max Operating Voltage	138kV / 145kV
Lightning Impulse Withstand Voltage	650 kV BIL
Typical Surge Arrester	Size based upon Insulation Coordination
System Grounding	Effectively Grounded Neutral (always)

115kV Substation Electrical

Line Terminal & Equipment Continuous Current	2,000A minimum, but designed to application
3 second short circuit current	40kA minimum, but designed to application
Operating Voltage (Transformer must accommodate this	115kV / 121kV
Lightning Impulse Withstand Voltage	550 kV BIL
Typical Surge Arrester	Size based upon Insulation Coordination
System Grounding	Effectively Grounded Neutral (always)

69kV Substation Electrical

Line Terminal & Equipment Continuous Current	2,000A minimum, but designed to application
3 second short circuit current	40kA minimum, but designed to application
Operating Voltage (Transformer must accommodate this	69kV / 72.5kV
Lightning Impulse Withstand Voltage	350 kV BIL
Typical Surge Arrester	Size based upon Insulation Coordination
System Grounding	Effectively Grounded Neutral (always)

4.2 FUNCTIONAL CRITERIA:

When evaluating a proposed electrical interconnection the designated entity shall consider physical as well as electrical characteristics. This can be done to a certain degree by evaluating the arrangement using the following criteria:

1. The clearing of failed Transmission Owner facility equipment, shall not adversely affect any other TO's facilities. This generally means that there could be one or more intertie breakers. While this breaker need not be located at the POI, it should be the first element in the adjacent stations. No load, circuits, transformers, or other elements shall be tapped off the interconnection facility prior to its isolation.

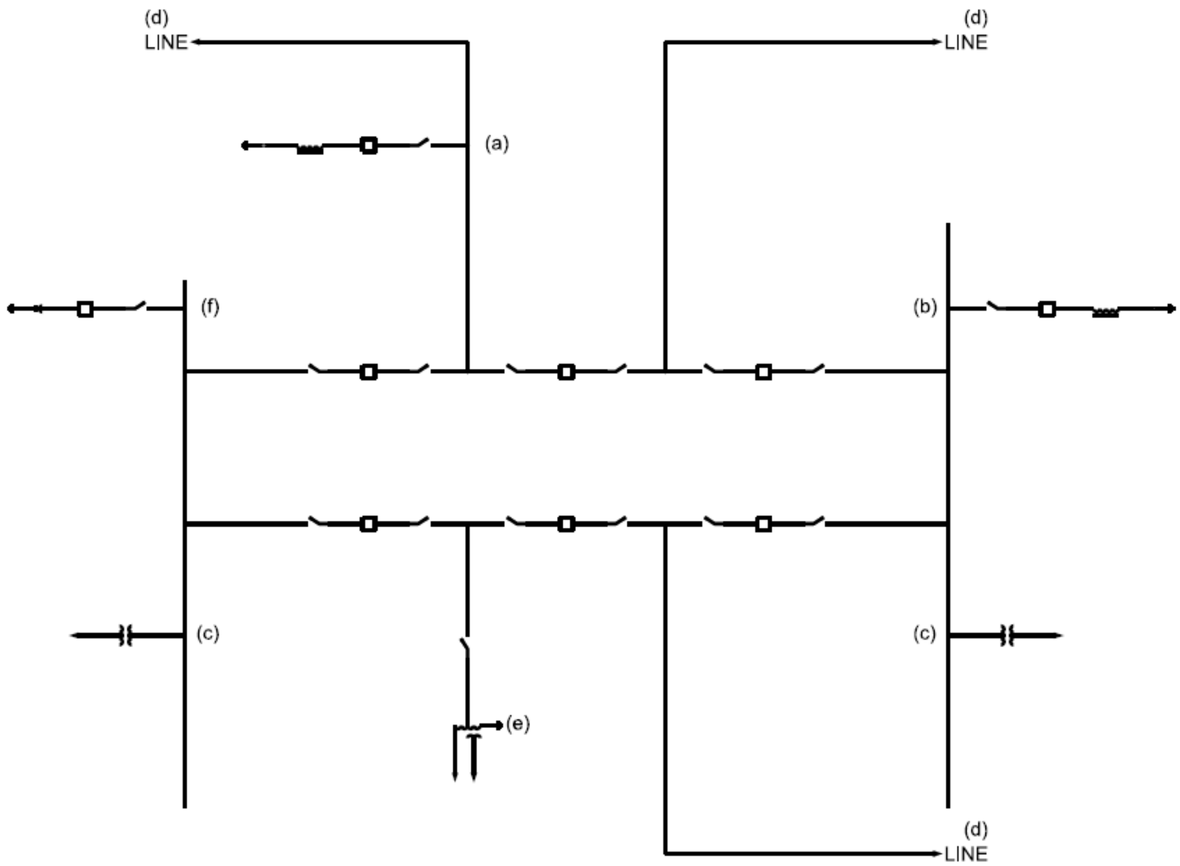
2. The arrangement of circuits and breaker bays shall be considered such that a stuck breaker operation will not trip two circuits on the same double circuit tower line.
3. Multiple ties should be provided between buses for all conditions, including situations where at least one transmission line or station breaker is out of service for maintenance.
4. Every attempt should be made to lay out stations such that a transmission conductor, towers/ poles, or a static wire that drops within the switchyard area should not cause another transmission circuit to trip. This means that line crossings within the switchyard fence should be avoided and there should be adequate spacing between bays to minimize the possibility of a falling wire contacting another line's phase conductor. If this cannot be accomplished the configuration should be evaluated to assure no unacceptable conditions could result from the postulated failure.
5. Electrical equipment within the station must be adequately spaced to:
    - Facilitate equipment replacement
    - Facilitate maintenance activities and associated maintenance equipment
    - Minimize the likelihood that catastrophic failure of a single piece of equipment will adversely impact adjacent equipment.
    - Minimize possibility of total station outage
6. Consideration shall be considered to be given to the distribution of supply and load connection within the station. The connection of circuits and transformers into the station should be arranged to balance flows throughout the station bus. This can be accomplished by alternating the connection of elements anticipated to inject flow with those anticipated to supply load from the station. The objective is to balance flows in the station to reduce bus loading.
7. There will be no customer load served, except for station service, from the transformer's tertiary.
8. In addition to these criteria the following factors must be reviewed and weighed appropriately in performing the assessment of a substation configuration:
    - Operational complexity and flexibility
    - Reliability for the load
    - Reliability for transmission lines and substation equipment
    - Generator interface
    - Line Maintenance
    - NERC, MAAC requirements/criteria
    - Expandability/Adaptability
    - Safety
    - Changes in technology
    - Cost (capital and O&M)
    - Availability of spare equipment
    - CIP / Security

4.3 Bus Configuration

For the bus configuration, an element is classified as a line, or an equipment connection including transformers and devices providing reactive support (capacitor, shunt reactor, SVC, or other FACTS devices), which have a direct connection to the bus. The following equipment are not considered elements:

- Shunt reactor connected to line
- Series reactor
- Series capacitor
- Station service voltage transformer (SSVT)
- Instrument transformer

Every element shall have a form of high side protection device with fault clearing capabilities. The failure or maintenance outage of an element cannot remove another transmission line from service for any time increment. Refer to Figure 1 for a depiction of elements and non-elements on a One-Line diagram.



(a) Shunt reactor connected to line (Not an Element)
Note: Required only for particular applications with open end line voltage or to control high voltage due to light load conditions.
(b) Shunt reactor connected to bus (Element)
(c) Station service voltage transformer (Not an Element)
(d) Line (Element)
(e) Power Transformer (Element)
(f) Shunt capacitor connected to bus (Element)

Figure 1 – One-Line diagram showing elements and non-elements

All elements inside the substation must include a fault clearing device to limit the exposure of failures of one element to only the affected element. Isolation or maintenance of an element should not affect the operation of another element. If a capacitor or shunt reactor is to be regularly switched due to system conditions, a switching device is required specific for that element so the ring or breaker-and-a-half configuration is not opened for each switching operation.

Substation busses with voltages less than 200kV must at a minimum meet the criteria outlined above and following the criteria for substations greater than 200kV is recommended, but not required.

Substation busses with voltages greater than 200kV must be designed at a minimum based on the following parameters:

- 3 to 6 elements connected in a normally closed configuration – requires a ring bus connection at a minimum
- 7 or more elements connected in a normally closed configuration – requires a breaker-and-a-half design at a minimum

Stations may have the options for future expansion capabilities for future growth and expansion (e.g., converting ring bus to a breaker-and-a-half as terminals are added). If the solution/design includes future expansion capabilities, the expansion should be outlined for potential evaluation.

Deviations from the above minimum design criteria are acceptable if required to meet all NERC PJM, and Transmission Owner criteria without jeopardizing operating standards and reliability. As all of the above are minimums, each project design can be designed to higher reliability and operating standards based upon the specific project needs.

NOTE: Three terminal lines are not permitted in the PJM footprint at 200kV and above.

4.4 ACCESSABILITY AND LAYOUT:

Adequate space and firm vehicular surface shall be provided on at least one side of each major piece of electrical equipment. Access is required to permit O&M vehicles, including bucket trucks and cranes, to access electrical equipment for any reason without requiring the de-energization of adjacent electrical equipment. The design must also accommodate minimum approach distances (MAD) as part of the layout and arrangement. In a breaker bay this access must be provided the full length of the bay and must not be encumbered by overhead electrical equipment or conductors. Appropriate stone or asphalt roadway shall be provided. For indoor GIS equipment a bridge crane may be used in lieu of roadways as long as this approach provides a feasible means to conduct maintenance including the removal and replacement of all major equipment.

Electrical equipment shall be arranged with adequate clearance for maintenance activities and for associated maintenance equipment, such that only the equipment to be maintained, including its isolating devices, needs to be operated and/or de-energized for the maintenance work to be performed. Depending on the criticality of the facility, each transmission lines and transformer may need to be equipped with a switch to isolate it from the substation such that the station bay or ring bus can be re-energized during maintenance of that transmission lines or transformer.

Electrical equipment shall be arranged with adequate clearances such that a catastrophic failure of equipment associated with one circuit is unlikely to adversely affect equipment associated with another circuit. The layout must accommodate considerations and requirements for fire protection separation distances and fire ratings must be suitable per IEEE 979 at a minimum for fire protection guidance.

A driveway must be provided around the perimeter of the station for vehicle movement. In addition, permanent driveways must be provided to transport all equipment in and out of the station. Each of these driveways must be adequate for the combined weight of the heaviest vehicles/equipment to be accessed. The station must be laid out such that the accessibility of all equipment is maintained in a manner that allows removal and replacement of all equipment throughout the life of the station.

Twenty-four hours, unobstructed access must be provided for the substation. Parking allowance for several vehicles must be provided adjacent to the relay/control house. The entrance gate must be double driveway width with the yard's safety grounding covering the open gate area.

The station should be suitably graded to facilitate water runoff and to direct spilled dielectric fluid away from other major electrical equipment and toward planned containment.

4.5 EQUIPMENT:

All equipment utilized inside the substation at a minimum shall be specified, designed, built, and tested in accordance with the IEEE and ANSI standards that govern such equipment.

4.6 ABOVE GRADE PHYSICAL:

All design and working clearances shall meet the latest requirements of the NESC, IEEE and OSHA standards. Additional clearance consideration for safety should be considered in areas where foot and vehicular traffic may be. Phase spacing shall not be less than IEEE 1427 and NESC requirements at a minimum.

The physical design must accommodate any through fault condition that may be present. All switching and transient levels must be addressed in the design.

All primary electrical connections utilized in stations 200KV and above must use welded, compression, or swage fittings. Bolted connections must be limited to connections made on equipment itself (bolting of connector to pads), or insulator support fittings. The system shall be designed per the latest IEEE 605 standard. All tubular bus work shall be designed and installed with the appropriate slip, fixed and expansion connections. All Extra High Voltage (EHV) connections 345kV and above must be corona free. Structural steel when used for support of equipment shall be hot dip galvanized.

The physical layout and design must be conducted to ensure proper maintenance and access is accounted for in the design. The design must also allow for sufficient space to maintain OSHA minimum approach requirements, either with or without tools.

4.7 INSULATION COORDINATION AND LIGHTNING PROTECTION:

General Requirements

Insulation coordination is the coordination of electrical insulation levels with overvoltage protection. It includes subjects of shielding from lightning, application of surge arresters, insulator contamination, switching surge mitigation, and temporary overvoltage control. The nominal voltage ratings of the effectively grounded transmission systems are defined as part of this Minimum Basic Insulation Levels (BIL) standard in the General Design Criteria section. All insulation shall be capable of operating at these continuous voltages, and withstanding the transient over voltages allowed by the overvoltage protection. IEEE C62.82.1 “Standard for Insulation Coordination–Definitions, Principles and Rules”, and IEEE 1313.2 “Guide for the Application of Insulation Coordination” should be followed when selecting surge arrester ratings and station and equipment insulation levels.

Shielding from Direct Lightning Strokes

All facilities connected to the PJM system shall be shielded from direct lightning strokes to meet the design criteria in these guides. IEEE Standard 998 “IEEE Guide for Direct Lightning Stroke Shielding of Substations” should be used as guide in designing lightning shielding. Lightning Shielding may be accomplished through, masts, overhead ground wires, or other tall conducting structures. Static wires not connected to or associated with the incoming line terminations should avoid crossing over busses and other circuits.

Arresters shall provide a 20% minimum margin of protection as recommended in the standard IEEE C62.22. This allows for insulation aging and contamination and higher incoming surge magnitudes and faster rise times. It is recommend maintaining 20% margin for breakers, switches and voltage transformers and 50% margin on power transformers.

Arrester shall be applied with adequate pressure relief or fault current withstand rating, and adequate energy capability.

Insulation Coordination Studies

An Insulation Coordination Study must be completed. Detailed studies including lightning traveling wave analysis, switching surge analysis, TOV analysis, Harmonic resonance, etc., may need to be conducted to balance the number and location of surge arresters with proposed insulation levels as required. EMTP and similar tools can be used in these studies.

Power Transformers will require surge arrester protection on all terminals. Additionally, line entrance arresters are required on all lines. Any frequently open position will be a positive reflection point for fast front transients and deserves special attention. Other non-self-restoring devices such as underground cable and accessories and Gas Insulated Switchgear (GIS) shall be protected by a dedicated set of surge arresters.

Specification of Surge Arresters

All surge arresters shall meet or exceed the latest applicable ANSI, IEEE, NEMA, NESC and OSHA Standards.

Surge Arresters shall be designed with adequate electrical and mechanical characteristics for the specific electrical system on which it is installed and for the application for which it is intended. These include but shall not be limited to: Maximum Continuous Operating Voltage (MCOV), Rated duty cycle voltage, energy discharge capability, Temporary Overvoltage capability, and environmental conditions.

Energy discharge capability must be sufficient to survive line or capacitor bank discharge from at least one maximum energy restrike of any switching device in the substation.

Surge arresters shall be designed for an in service operating life, comparable to other electrical apparatus in the system to which it is applied.

Surge arresters, at a minimum, shall be designed to operate at ANSI required ambient of -30_C to +40_C (-22_F to +104_F). All surge arresters shall be designed to operate satisfactorily in the ambient required by their installed location. Some locations in PJM require -40_C capability.

Local environmental conditions should be considered when selecting leakage distances requirements for Surge arresters and other components.

Application and Special Considerations

Surge Arresters generally should be located as close as practical to the equipment they are primarily installed to protect. Both the lead length and the ground return length need to be kept as short and straight as possible.

For example, when possible, surge arresters protecting power transformers should be mounted on the transformer, and the grounded end solidly bonded to the nearest ground that grounds the transformer. Also, incoming transformer lead should be connected to the arrester BEFORE the transformer bushing.

4.8 AC STATION SERVICE:

The following criteria must be met for the AC station service design:

1. There must be two AC sources such that a single contingency cannot de-energize both the primary and back-up station services. An automatic throw-over switch with an auxiliary contact for SCADA alarm is required to provide notification of loss of primary station service.
2. Loads are generally categorized by electrical size in determining the appropriate supply voltage. Typical voltages would be 480Y/277V, 208Y/120V, and 240/120V.
3. Distribution lines shall not be used as a primary source.
4. Station service transformers shall be protected by surge arresters.
5. Emergency generators may be required where black start capability is required.
6. Due to the large distances and auxiliary loads in 765kV and large EHV stations, multiple station service load centers may be required. The relay protective scheme must be selective and remove from service only the faulted station service transformer.
7. All station service transformers shall have high side overcurrent protection (via a fuse or a bus protection scheme if the transformer is tapped to the bus).
8. Transfer switches may be installed internal or external to their associated switchboards, however, if they are located externally, they shall be located adjacent to the switchboard to minimize the exposure of the single set of cables supplying the switchboard. For large electrical loads, such as a power transformer with oil pumps, dedicated transfer switches would be located at the power apparatus with primary and alternate power supplies. Electrical separation is required for this application and physical separation via separate cables at a minimum is required for the supplies routed to the switch.
9. All devices connected to the AC station service system must be capable of operating continuously and properly without malfunction or overheating in the voltage range specified by the designer of the system.
10. AC station service system components must be installed in accordance with manufacturer's instructions and applicable industry standards.
11. All AC primary and backup station service supplies shall be adequately monitored and alarmed, for all voltage levels and sources, to assure that improper operation and abnormal conditions are reported for immediate corrective action.
12. AC station service systems shall be physically arranged to facilitate safe and effective inspection and maintenance.
13. Critical transmission facilities shall be provided with emergency engine-generator sets sized to carry essential loads considering a reasonable diversity factor, when alternate reliable sources are not available. Essential loads are loads required to maintain normal operation of the station and the loads required to bring a station back online after a period of blackout. If not, facilities shall be available for prompt connection of emergency generation. Remoteness of the location, adversity of weather conditions, refueling cycles, etc. must be considered in determining required fuel capacity.

Requirements for AC Station Service:

1. As a minimum requirement, AC station service systems and equipment shall be designed for the purpose intended and be specified to meet latest requirements of all applicable industry standards, including but not limited to ANSI, IEEE, NEMA, OSHA and NESC.
2. AC station service equipment is available in varying degrees of quality. Equipment installed in a transmission facility shall be designed to operate reliably during the design life of the facility. This requires quality products and specifications that reflect this need.
3. Main distribution panels located on the load side of the fused safety disconnect switch shall have breakers rather than fuses. These breakers shall be designed to coordinate with each other to ensure proper protection.
4. All electrical contact parts and conducting mechanical joints should be properly plated and prepared to insure joints that have low resistance for the equipment's expected life.
5. AC station service cables may be run in the same tray systems as other AC circuits 480 volts and below and with 125vdc control circuits. However, they are not to be commingled with low voltage digital signal circuits and/or analog signal circuits such as data network, Ethernet, etc.
6. AC circuits shall be adequately sized and designed to limit the total voltage drop to no more than 5% continuous and 10% momentary. Greater voltage drops may be acceptable as long as the analysis determines it will not affect the operation or reliability of the equipment.

4.9 STATIONARY BATTERIES AND CHARGERS:

The following criteria must be met for the AC station service design:

1. Requirements for the battery design are to be incorporated on FERC based projects. These requirements are not required in projects required to support local distribution reliability and load as they are not governed by FERC. Stations 300kV and above whose configurations are designed to reinforce the flow of power on the transmission system, must follow the requirements outlined below.
2. Separate batteries for primary and back up protection are required. Each of these batteries must be fed by (1) independently supplied charger (each charger must have its own/ separate AC supply) at a minimum.
3. A single battery for all other requirements is acceptable. In this application, however, the battery must be supplied with two independently supplied chargers (each charger must have its own/separate AC supply) at a minimum.
4. The battery system shall be sized in accordance with the latest version of IEEE 485 Recommended Practice for Sizing Lead-Acid Batteries for Stationary Applications or IEEE-1115 Recommended Practice for Sizing Nickel-Cadmium Batteries for Stationary Applications for a minimum duty cycle of no less than 8 hours with the most severe possible multiple breaker operation (usually bus differential operation) at the end of the cycle. It must be taken into consideration when sizing the battery the distance to the site in order to perform an emergency replacement. This distance may require a minimum duty cycle of more than 8 hours.
5. Correction factors shall be included in battery sizing calculations to account for temperature conditions, battery aging and potential load increases.

6. Provisions must be made to facilitate the replacement of a failed charger or battery bank without interruptions to the DC system.
7. The battery charger shall be able to supply the station DC power requirement and at the same time to bring the station battery to “fully charged” condition in less than 24 hours following a prolonged discharge period due to an AC power failure.

Requirements for Battery and Charger

1. As a minimum requirement, battery and charger systems must be designed for the purpose intended and shall be specified to meet the requirements of all latest applicable industry standards, including but not limited to ANSI, IEEE, NEMA, OSHA and NESC.
2. The charger shall be protected by automatic current limiting, and be self-protecting against transients and surge voltages, and be designed to prevent the battery from discharging back into the internal charger load.

Application and Installation for Battery and Charger

1. When multiple battery and charger systems are provided to supply multiple relay systems (referred to as primary and backup or system one and system two), the batteries and chargers, including all associated wiring, are to be kept physically and electrically separated to avoid a problem with one system affecting the other system.
2. Batteries shall be installed in facilities that assure that appropriate ambient temperatures are maintained and that the batteries are not exposed to direct sunlight.
3. Battery systems shall be installed in accordance with manufacturer’s instructions and applicable industry standards, with special attention given to cell handling and cell connections and protection.
4. Before a battery and charger system is placed in service, appropriate acceptance testing shall be conducted and appropriate data, such as cell voltage and specific gravity, shall be recorded for future use.
5. Batteries shall be physically arranged to facilitate safe and effective inspection and maintenance. This requires a 3ft. work area in front of the batteries for replacement and maintenance activities.

DC Station Service

Application and Installation of DC Station Service

1. DC station service system components shall be installed in accordance with manufacturer’s instructions and applicable industry standards.
2. All devices connected to the dc station service system shall be capable of operating continuously and properly without malfunction or overheating in the voltage range specified by the designer of the system.
3. The output cables from the battery to the first breaker or protective device in the main DC panel shall be kept as short as practical; shall be separately routed to reduce the possibility of a short circuit between the positive and negative cables; shall be installed in conduit for protection; and shall be sized in consideration of the available dc short-circuit current from the battery.

4. DC station service systems must be adequately monitored and alarmed to assure that improper operation and abnormal conditions are reported for immediate corrective action.
5. DC station service systems shall be physically arranged to facilitate safe and effective inspection and maintenance.

Requirements for DC Station Service

1. As a minimum requirement, DC station service systems and equipment shall be designed for the purpose intended and be specified to meet the requirements of all applicable industry standards, including but not limited to ANSI, IEEE and NEMA.
2. The typical nominal rating for this application is 125 VDC.
3. The DC system design must take into consideration the voltage drop between the battery and the load terminals. Under no circumstances should the voltage at each load terminal be less than the manufacturers' specifications. Age, cell failures, and good engineering judgment must also be considered when designing and shall be considered in the initial voltage level of the batteries.
4. The maximum load terminal voltage shall not exceed the product of (the number of cells in battery) times (the maximum defined cell voltage).

4.10 GROUNDING:

The station ground grid shall be designed in accordance with the latest version of IEEE Std. 80, Guide for Safety in AC Substation Grounding. The fault current calculations should include future improvements which would increase the fault current. It is recommended that the ground grid be designed for a fault current growth factor of 20%.

4.11 RACEWAYS:

Design Considerations:

- Design of the raceway and conduit system shall consider the anticipated station build out.
- Troughs shall be routed with sufficient clearance from oil filled equipment to minimize an oil fire in the trough.
- All outdoor raceway components shall be designed for the environment which they are installed in.
- "Primary" and "Backup" systems cannot be in the same cable.
- Long cable runs that parallel to high voltage bus and transmission lines shall be avoided in the design of the trench system.
- All cables rated greater than 1kV shall not be installed in the same trench system as cables less than 1kV.
- All Conduits shall be installed to provide protection from vehicular and environmental conditions.
- Consideration of water flow must be considered when designing the conduit/trench system to ensure excess water flow does not back up in the equipment, cabinets or control house.

Below Grade:

- Typically the outdoor main runs of the raceway/conduit system are surface mounted with its cover sitting flush with finished grade. No direct buried cable shall be permitted.
- Proper drainage shall be included underneath the trench.
- Where vehicles will cross the conduits or trench system, suitable covers and design must be incorporated to protect the cables from the heaviest vehicles and equipment anticipated on crossing the roadway.
- Below grade conduits shall be used to complete the run from the main trench system to the equipment.
- No more than 360 degrees of bends should be installed in a conduit run.
- All metallic conduits shall be bonded directly or indirectly to the ground grid.

Above Grade:

- All cable trays and junction boxes shall be bonded directly or indirectly to the ground grid.
- Fiber shall be routed and protected either in its own separate tray, conduit, or other protective medium such as innerduct.
- All above grade outdoor conduit shall be suitable for the environment in which it is installed in.
- Vertical raceways on control building sidewall should be sized to accommodate the ultimate layout of the substation.

4.12 CONTROL HOUSE OR ENCLOSURE:

General Requirements

The enclosure shall be suitably designed and constructed to contain all substation control and instrument panels, relay panels, metering panels, AC lighting and power panels, Annunciator, DFR, SCADA equipment, DC station batteries, DC Power Panels, fire alarm panel, battery chargers, toilet facilities (when required), office furniture, HVAC equipment, and local required telecommunications. Consideration shall be given to either sizing the enclosure to accommodate the needs of the ultimate station development or to allow for the expansion for such accommodation.

Control Enclosure shall typically not be part of the Substation fence. In the event of a station located inside metropolitan areas and the building does need to be part of the fence, the outside walls shall be designed accordingly.

All materials and equipment used in the control enclosure shall be noncombustible to the greatest extent practical.

Fire detection system must be installed in control enclosures.

Specification

The enclosure shall be designed and constructed in accordance with the latest revisions of all applicable codes including but not limited to:

- ACI – American Concrete Institute
- AISC – American Institute of Steel Construction
- AISI – American Iron and Steel Institute
- ANSI – American National Standards Institute
- ASCE – American Society of Civil Engineers
- ASTM – American Society for Testing and Material
- AWS – American Welding Society
- IBC – International Building Code
    - International Plumbing Code
    - International Energy Code
    - International Mechanical Code
    - International Fire Code
- IEEE – Institute of Electrical and Electronics Engineers
- MBMA – Metal Building Manufacturers Association
- NESC – National Electrical Safety Code (IEEE C2)
- NEC – National Electric Code
- NFPA – National Fire Protection Association
- All applicable state and local building codes and requirements.
- Wind and ice loading criteria as found in the structural section of this document

Structural, Architectural, and Mechanical Requirements

The enclosure shall be as specified below:

1. The enclosure is not intended to be used as a shop.
2. The enclosure is not intended to be used as a storage location for spare parts.
3. The enclosure is not intended to be used for equipment assembly.

Enclosure design loads shall include live, snow, wind, seismic, and dead loads. In addition, enclosure must be designed to carry the auxiliary static loading from interior cable tray systems and air handling ductwork, and additional electrical equipment such as lighting, battery chargers, power panels etc. The floor space supporting the supplied loads need to be braced to handle the weight associated with those loads.

Falling ice: Exterior of control enclosure shall be designed to resist damage by hail and falling ice from adjacent structures or overhangs.

Doors:

1. Typically, two exits with panic bar and door holder mechanism will be required. It is recommended that one exit be a double door and the second exit be a single personnel door. The doors need to be sized and configured to allow delivery of relay panels and other large equipment deliveries. A roll up garage door is acceptable in lieu of double doors.
2. Weather stripping shall be included around all edges.
3. Means for locking and securing all doors shall be included.

Enclosure ceiling, floors and walls shall be insulated. Vapor barriers shall be provided.

Gutters, downspouts, and splash block diffusers shall be considered.

Separate physical cable entrances shall be provided for each AC station service primary and back-up feed. Control cable entrances shall be sealed off to prohibit rodents from entering.

Heating, Cooling, and Ventilation

The enclosure shall be equipped with sufficient heating, cooling, and ventilation equipment to provide acceptable ambient temperatures within the enclosure so as not to impact the operation and life expectancy of the control equipment within.

Automatic temperature control equipment shall be installed. Microprocessor relay and control equipment and the control battery manufacturers should be consulted to establish proper ranges of operation.

Adequate ventilation shall be provided to prevent the accumulation of hydrogen gasses resulting from battery operation. Forced ventilation shall be used when required.

Illumination

See Table 111-1 of the National Electrical Safety Code for minimum illumination levels.

Emergency lighting shall be provided. Automatic initiation may be required. Illumination levels must meet the minimum requirements specified by the National Electrical Safety Code for egress.

Exterior lighting at doorways shall be provided to effect safe access to the enclosure.

Exit signage and emergency lights shall be provided in accordance with local codes.

Grounding

Structural enclosure steel, raceways, relay and control panels, AC and DC distribution panels (not the DC control voltage itself) shall be bonded to the station ground grid in accordance with the NESC.

Each control and relay panel shall be equipped with a ground bus to which instrument transformer secondary circuits or other equipment such as relay case grounds can be grounded.

Cable tray system shall be grounded and adequately bonded without creating a loop for circulating current.

Application and Special Considerations

Raceways

Control cables are to be installed in overhead cable tray raceway, or under the floor if a raised computer floor is used, or in under floor cable troughs. Raceways are to be suspended from enclosure ceiling or walls as required. Cable tray shall be aluminum or galvanized steel construction and be sized adequately for anticipated cable loads. Vertical cable risers shall be provided to physically protect its associated cables (i.e. vertical ladder tray, marshalling cabinets, etc.).

Nonmetallic jacketed cables below 7 feet above the floor level not in ladder tray or otherwise suitably protected shall be enclosed in conduit.

Working Space

A minimum of 3 feet working clearance shall be provided in front of all panels/batteries and 3 feet in back of panels where rear connected equipment access is required. See NESC Rule 125 for additional information.

Safety Equipment

Signage as required by NESC, OSHA, and other applicable organizations shall be provided. Signage is to be in accordance with ANSI Standards Z535.1, Z535.2, Z535.3, Z535.4, and Z535.5, latest revision.

Fire detection and extinguishing equipment shall be installed in accordance with all applicable national and local codes.

Face shields and eyewash stations, if installed, shall meet applicable OSHA requirements.

Provisions for containing acid spillage from the control battery shall be included in design of the facility.

Metering, System Protection, Annunciator, DFR, SCADA, and Telecommunications

The local telecommunications provider shall be consulted for their requirements for space, access, conduit size and routing, working clearances, auxiliary power, grounding, and other aspects of the installation. Isolation equipment may be required to protect telephone equipment from ground potential rise.

Free standing or rack mounted panels are acceptable.

Control panels and equipment shall be arranged in such a manner to allow for safe and reliable operation and maintenance activities of the substation.

4.13 STATION SECURITY:

Substations need to be designed to the requirements of the applicable NESC, IEEE, NERC and CIP publications.

4.14 STRUCTURAL:

Structural Design Loads

Structures, insulators, hardware, bus, and foundations shall be designed to withstand various load conditions based upon the NESC and when required the ASCE-7 code using the weather maps provided in the code. These loads will include various combinations of gravity, wind, ice, conductor tension, construction, maintenance, fault loads, and seismic loads (where applicable).

The magnitude of all weather and seismic related loads, except for NESC or other legislated loads, shall be determined using risk category IV criteria as defined in ASCE- 7 “Minimum Design Loads for Buildings and Other Structures.”

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

- ACI 318: Building Code Requirements for Structural Concrete and Commentary
- ACI 336.3R: Report on Design and Construction of Drilled Piers
- TMS 402/602 Building Code Requirements and Specifications for Masonry Structures
- ACI 543R: Guide to Design, Manufacture and Installation of Concrete Piles
- AISC 360: Specification for Structural Steel Buildings
- ASCE/SEI 7: Minimum Design Loads for Buildings and other Structures
- ASCE 10, Design of Latticed Steel Transmission Structures
- ASCE/SEI 48: Design of Steel Transmission Pole Structures
- ASCE 113: Substation Structure Design Guide
- ASCE Manual No. 104, Recommended Practice for Fiber-Reinforced Polymer Products for Overhead Utility Line Structures
- ASCE Manual No. 123, Pre stressed 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
- IBC: International Building Code

Dead-End Structures and Shield Wire Poles

Dead-end structures and shield wire poles shall be designed for the wind and conductor loading criteria, load combinations, and deflection criteria described in NESC C2 and ASCE 7. The following load cases shall be completed during the study, NESC Heavy, NESC Unfactored, Heavy Wind, Wind & Ice, Heavy Ice, and Extreme Cold to satisfy the requirements of the above stated standards. The design must be completed to ultimate strength design.

Equipment Structures and Masts

Substation structures shall have sufficient strength to resist all loads as defined in ASCE MOP 113, the NESC, and the load combinations defined below (including proper wind loads and orthogonal directions). The effects of gravity, wind, ice, wire tension, short circuit, seismic, construction & maintenance and operating loads shall be included as applicable.

The following load combinations apply to the substation equipment, equipment supports. The load combinations do not apply to buildings, lightning masts, fire walls, or transmission line dead-end and suspension structures. Structure design shall be ultimate strength using the methodology set forth in the ASCE 113 Guide for Design of Substation Structures (ASCE Guide), in addition to the following load combinations outlined below.

- 1.5 × Dead w/o Ice + 1.6 × Concurrent Wind on iced Structure and Equipment + 1.0 × Short Circuit Load + 1.65 × Conductor Tension
- 1.5 × Dead w/o Ice + 1.6 × Extreme Wind on Bare Structure and Equipment + 1.0 × Short Circuit Load + 1.65 × Conductor Tension
- 1.4 × Dead Load with Heavy Ice

Deflection Calculation

- 1.0 × Dead w/o Ice + 0.8 × Extreme Wind on Bare Structure and Equipment + 1.0 × Conductor Tension
- 1.0 × Dead w/ Ice + 0.8 × 0.75 × Concurrent Wind on Iced Structure and Iced Equipment + 1.0 × Conductor Tension

Earthquake

Per ASCE 113 – Yard/ Structures

Per ASCE 7 – Control Enclosure

- Site specific geotechnical investigation is required to determine site soil classification
- USGS Design Information per the USGS Seismic Design Maps

Rigid bus and bus supports

The following load combinations and load factors shall be used for evaluation of the indicated bus system components. In addition to the combinations shown, load cases shall also include any forces resulting from the thermal expansion of the bus due to current heating effects.

Typically the conditions of maximum icing do not usually occur simultaneously with maximum wind speed conditions. Therefore, two separate wind case loadings shall be considered. The full wind force shall be applied to the bus diameter when no ice is present. The concurrent wind speed shall be used in combination with ice. This reduced wind force is applied to the iced diameter of the bus.

An overload factor of 1.0 is considered sufficient for use with short circuit forces in these load combinations.

Load Combinations for Rigid-Bus Tubing & Equipment Terminal Pads

Per IEEE 605

The elastic limit stress shall be used for strength evaluation of the rigid-bus material when considering loading combinations without short circuit forces. When short circuit forces are included in the loading combination, the yield strength of the material shall be used for strength evaluation. Forces on switch terminal pads shall be limited to one-half the cantilever strength of the switch insulator, using these unfactored load combinations.

- 1.0 (Dead Weight) + 1.0 (Wind on Bare Surfaces) [Note: No ice loads]
- 1.0 (Dead Weight) + 1.0 (*" Radial Ice) + (*Wind on Iced Surfaces)
- 1.0 (Dead Weight) + 1.0 (Wind on Bare Surfaces) + 1.0 (Short Circuit)
- 1.0 (Dead Weight) + 1.0 (*" Radial Ice) + (*Wind on Iced Surfaces) + 1.0 (Short Circuit)

*Actual Ice and Wind load values to be determined based upon ASCE 113.

Load Combinations for Insulators

Insulator loads based on these loading combinations shall be compared with the minimum published cantilever and torsional strength ratings. When applicable, the combined effects of torsion and bending shall be evaluated.

- 1.5 × Dead w/o Ice + 1.6 × Concurrent Wind on iced Structure and Equipment + 1.0 × Short Circuit Load + 1.65 × Conductor Tension
- 1.5 × Dead w/o Ice + 1.6 × Extreme Wind on Bare Structure and Equipment + 1.0 × Short Circuit Load + 1.65 × Conductor Tension
- 1.4 × Dead Load with Heavy Ice

Foundations

Foundation reactions shall be determined from the load cases and load combination defined above. Load Factors shall be a minimum of 1.0. Unfactored loads shall be used for the foundation overturning and soil bearing design. Factored loads shall be used for the design of reinforced concrete per the requirements of ACI.

Deflection of structures shall be limited such that equipment function or operation is not impaired, and that proper clearances are maintained.

A site-specific geotechnical study shall be the basis of the final foundation design parameters.

4.15 CIVIL:

The substation shall be developed in accordance with all the federal, state, and local jurisdiction requirements. These requirements can consist of public safety, zoning, noise levels, poor drainage, wetlands, and aesthetic requirements. Site grading shall be completed to ensure excess runoff is accounted for in the design and ponding does not occur inside the substation. The grading design shall also consider the transition from substation ground pad to the existing grade. Storm water management and erosion control shall be designed with reference to the state and local permitting requirements.

Containment facilities and/ or Spill Prevention Plan may be required for equipment or storage tanks that contain dielectric fluid or fuel.

Roadways shall be designed in accordance with the requirements of the FHWA and AASHTO for large truck and trailer deliveries. Consideration should be given to ease of ingress and egress. Minimum turning radii for equipment shall be considered in the design. Special consideration shall be considered for vehicular access related to transformer hauling equipment, which may include the use of enlarged turning radiuses. Consideration should also be given to access transmission structures located outside the fence within proximity to the substation yard.

System Protection Engineering and Design Minimum Required Standards

5.0) System Protection Engineering and Design Requirements for Facilities that Interconnect to Existing Incumbent Transmission Owners (All Voltage Levels requiring the signing of a DEA)

For transmission circuits and other facilities with protective zones that are shared with existing incumbent Transmission Owners (i.e., facilities that represent ties between existing substations owned by incumbent Transmission Owners and Designated Entity substation facilities, etc.), the parties must coordinate to develop a protection system design that does not degrade the performance or reliability of the system, following the applicable technical requirements and standards of the Transmission Owner that are posted on PJM's website per Manual 14C Section 6.1.3.2., or other mutually agreed to solution for the items listed below. PJM Manual 07 will apply to all aspects of projects subject to the DEDSTF requirements. When interconnecting to multiple Transmission Owners systems, all parties must coordinate to achieve a mutually agreed upon solution.

The following are examples (including but not limited to) of design requirements that must be coordinated between parties.

- Line relay scheme (DCB, POTT, current diff, etc.)
- Line relay types/models
- Line protection communication media (Fiber, Power Line Carrier, etc.)
- Line protection communication scheme requirements – number of channels, channel types (POTT, DCB, DTT, etc.), and channel performance requirements
- Line Relay Setting and Trip Logic Design
    - Design must include sufficient test switches to allow isolation of protection system components and to provide adequate isolation to maintain protection system components and minimize trips caused by testing
- Reclosing method (HBDL, sync check, etc.) and associated timing must be coordinated with the local TO

5.1 System Protection Requirements for Facilities that exist within a developer's station and Do Not Directly Interconnect with Existing Substations Owned by Incumbent Transmission Owners

Facilities with protective zones that are not shared with incumbent Transmission Owners or Generation Owners are not subject to DEA section 4.2 (i.e., facilities entirely within a Designated Entity substation or a facility that interconnects two Designated Entity substation facilities, etc. PJM Manual 07 will apply to the following Designated Entity equipment as minimum design standards for system protection, metering, and control:

- Substation Buses (Manual 07, Section 9)
- Breaker Failure Protection (Manual 07, Section 12)
- Transmission Substation Transformers (Manual 07, Section 8)
- Shunt Reactors and Capacitors (Manual 07, Section 10 and 11)

- Phase Angle Regulating and Voltage Regulating Transformers (Manual 07, Section 13)
- HVDC Transmission Circuits and Converters (No Coverage in Manual 07)

Note 1: Minimum system protection requirements for HVDC Transmission Circuits and associated converter equipment shall be determined on a case-by-case basis and included in the applicable PJM Problem Statement & Requirements Document. At a minimum, completely redundant protection systems will be required for these elements.

Note 2: For phase angle regulators (PAR) at a Designated Entity station that are electrically located at the terminal of a transmission line with a shared protection zone, design and relay setting coordination between the Designated Entity facility and the incumbent Transmission Owner facility is required. The required protection schemes on a PAR are inherently complex, and can adversely affect reliability of the incumbent Transmission Owner system. In these cases, agreement on scope of design and protection philosophy, relay settings and test methods may be required by the incumbent Transmission Owner.

Note 3: Breaker failure design, timing requirements and relay types must be coordinated between the Designated Entity and the Incumbent Transmission Owner prior to the design of the protection system for all breakers in the Designated Entity station. Where generator stability is a concern, the protection requirements must be fully understood by the Designated Entity prior to the selection of relay types and overall design of the breaker failure scheme.

5.2 System Protection Requirements for Facilities below 200kV

For protection systems in the substation subject to a Designated Entity Agreement that do not meet the applicability of PJM Manual 07, Appendix A lists the minimum requirements for those protection systems.

5.3 Appendix A

This appendix outlines the protection requirements for the protection of greenfield project facilities at or above 46kV and below 200kV.

Generator Protection

For generating units less than 100 MVA and connected below 200 kV, see PJM M07 Appendix D

Unit Power Transformer and Lead Protection

PJM Manual 07 Section 4 applies for unit power transformers and associated high-side leads where the transformers are (1) rated less than 100 MVA, or (2) are connected to utility systems at transmission system voltages below 200kV.

Unit Auxiliary Transformer and Lead Protection

PJM Manual 07 Section 4 applies for unit power transformers and associated high-side leads where the transformers are (1) rated less than 100 MVA, or (2) are connected to utility systems at transmission system voltages below 200kV.

Start-up Station Service Transformer and Lead Protection

PJM Manual 07 Section 6 applies for start-up station service transformers and associated high and low-side leads connected to transmission systems at system voltages below 200kV.

Line Protection

PJM Manual 07 Section 7 applies for the protection of lines at system voltages below 200kV except for following requirements:

Primary Protection

- For transmission lines below 200kV, pilot protection may be required to meet coordination requirements of the interconnected Transmission Owner.

Restricted Ground Fault Protection

- For transmission lines <200kV, restricted ground fault protection may be required to meet coordination requirements of the interconnected Transmission Owner.

Substation Transformer Protection

PJM Manual 07 Section 8 applies for the protection of substation transformers with high-side voltages of below 200kV except for following requirements:

Current Differential Zone Considerations

- M07 applies except, separate restraint windings in the differential relays are Not required for substation transformers with high-side voltages below 200kV

Isolation of a Faulted Transformer Tapped to a Line

- PJM Manual 07 Section 8.2 applies since bulk power lines operated below 300 kV may be tapped with the concurrence of the transmission line owner(s).

Protection Scheme Requirements

- A device failure scheme for the fault interrupting device is not required for substation transformers with high-side voltages below 200kV.

Transformer Leads Protection

- High and low side leads of transformers with high-side voltages below 100kV must be protected by two independent schemes, only one of which must be high-speed. If the leads are included in a line protection zone, transformer lead protection is not required.

Bus Protection

For the protection of substation buses at system voltages below 100kV, one high speed protection scheme is required for protecting the bus. Remote or local protection is required as a backup. The schemes must utilize independent current and/or voltage sources and independently protected DC control circuits.

Shunt Reactor Protection

PJM Manual 07 Section 10 applies for the protection of shunt reactors at system voltages below 200kV.

Shunt Capacitor Protection

PJM Manual 07 Section 11 applies for the protection of shunt capacitors at system voltages below 200kV with the following exception:

Unbalance Detection Scheme

- For facilities below 200kV, one capacitor bank unbalance detection scheme must be installed.

Breaker Failure Protection

PJM Manual 07 Section 12 applies for breaker failure protection at system voltages below 200kV with the following exception:

Local breaker failure protection requirements

- For facilities below 100kV, a dedicated breaker failure scheme shall be used for each fault-interrupting device and shall initiate tripping of all local sources of fault current if the remote backup protection is inadequate.

Phase Angle Regulator Protection

PJM Manual 07 Section 13 applies for the protection of phase angle regulating transformers connected at system voltages below 200kV.

Transmission Line Reclosing

PJM Manual 07 Section 14 applies for automatic reclosing schemes for fault interrupting devices at system voltages below 200kV.

Supervision and Alarming of Relaying and Control Circuits

PJM Manual 07 Section 15 applies for supervision and alarming of relaying and control circuits applied to protect equipment at system voltages below 200kV.

Underfrequency Load Shedding

PJM Manual 07 Section 16 applies for underfrequency load shedding schemes at system voltages below 200kV.

Special Protection Schemes or Remedial Action Schemes

PJM Manual 07 Section 17 applies for Special Protection Schemes (SPS) or Remedial Action Schemes (RAS) at system voltages below 200kV.

Use of Dual Trip Coils

The use of dual trip coils in circuit breakers is not required at system voltages below 100kV

Direct Transfer Trip Requirements

The use of dual trip coils in circuit breakers are not required at system voltages below 100kV

Dual Pilot Channels for Protective Relaying

PJM Manual 07 Appendix C applies for facilities below 200kV.

Small Generator Protection Requirements

PJM Appendix D applies for generating units less than 100 MVA and connected below 200kV.

Acceptable Three Terminal Line Applications

PJM Manual 07 Appendix E applies for facilities below 200kV with the following exception:

Protection Requirements

- For facilities below 200kV, directional comparison blocking (DCB) or unblocking scheme (DCUB) operating over power line carrier to a third terminal is acceptable for primary or backup line protection.

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