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INTRODUCTION:

The PJM Designated Entity Design Standards Task Force (DEDSTF) were formalized by PJM to conform in part to FERC Order 1000. They are intended to apply to facilities proposed/requested in accordance with the process defined in the Open Access Transmission Tariff ("OATT"). They are intended to provide common PJM transmission provider criteria concerning design philosophy, design requirements and operating practices for Transmission Facility Owners. These guidelines are intended to be the minimum guidelines to which any entity must design and built to in the PJM territory. Transmission Owners ("TO's") traditionally have additional more specific requirements based on the needs of their systems and to ensure the reliability of the Transmission System, which may be greater than these Technical Requirements referenced throughout this documentation.

The user of these Technical Requirements must review all PJM criteria and documents referenced throughout these sections to ensure proper detail and knowledge of the guidelines is considered. Also noting that these standards must comply with all PJM Transmission, Substation and Protection and Control Standards as indicated. While this document describes details, criteria and philosophy, it is also understood that all other standards shall be followed at a minimum, including, but not limited to IEEE, FERC, NERC, NESC, ect.

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 substations. 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 minimum required N and W of Blue Mountain)
Wind loading Substations (no ice) Wind loading Lines (no ice) 138kV or less Wind loading Lines (no ice) greater than 138kV	-per ASCE 7-98, Figure 6-1 depending on location [typically 90 to 110 mph] per NESC Extreme Wind 25psf or NESC Extreme Wind (whichever is greater)

Ice load 500kV, 345kV, 230kV lines (no	38mm radial ice
Ice load substations (no wind)	25mm radial ice
Wind coincident with 13mm radial ice	40mph (64km/h)
Seismic Substations	per ASCE 7-98 0.2 s and 1.0s Spectral Response Acceleration (5% of Critical Damping), Site Class B.(Figure 9.4.1.1 (a) & (b)) Equipment qualification per IEEE 693-97. [Typically 0.2g some as high as 0.4g]
Line design	NESC Heavy (latest edition) and Clause IV A
Flood Plain	Structure ground line above 100yr flood where

765 kV Substations Electrical (copy from 500 kV)

Line Terminal and Equipment Continuous	3000A
3 second current (short circuit)	40kA (X/R 25) DC time constant 60ms
Operating Voltage (Transformer must accommodate the voltage range expected at the point of	450kV to 550kV 500kV nominal (typical "normal" voltages range from 515kV to 550kV)
RIV level @ 350kV line to ground	300uV @1MHz
Lightning Impulse Withstand Voltage w/o line entrance	1800kV
Lightning Impulse Withstand Voltage **with** line entrance arresters	1550kV
Switching Impulse withstand level (20)	1050kV
Typical Surge Arrester	318kV MCOV Station Class (396kV duty cycle)
Circuit Breaker line closing switching surge factor	2.2 (i.e. closing resistors required & no restrikes, or line end arresters used to clamp switching
System Grounding	Effectively Grounded Neutral (always)
Lightning trip out Performance (station)	1/100years Keraunic level =40
Fault performance (circuit failure, including momentary) all other causes	1/40 years/breaker position

500kV Substations Electrical

Line Terminal and Equipment Continuous	3000A
3 second current (short circuit)	40kA (X/R = 25) DC time constant 60ms { higher duties required at some locations usually < 63kA}
Operating Voltage (Transformer must accommodate the voltage range expected at the point of	500 kV to 550kV 500kV nominal (typical "normal" voltages range from 515kV to 550kV)
RIV level @ 350kV line to ground	300uV @1MHz
Lightning Impulse Withstand Voltage w/o line entrance arresters	1,800 kV
Lightning Impulse Withstand Voltage **with** line entrance arresters	1,550 kV
Switching Impulse withstand level (20)	1,050 kV
Typical Surge Arrester	318 kV MCOV Station Class (396kV duty cycle)

Circuit Breaker line closing switching surge factor	2.2 (i.e. closing resistors required & no restrikes, or line end arresters used to clamp switching overvoltages.)
System Grounding	Effectively Grounded Neutral (always)
Lightning trip out Performance (station)	1/100years Keraunic level =40
Fault performance (circuit failure, including momentary) all other causes	1/40 years/breaker position

345kV Substations Electrical

Line Terminal and Equipment Continuous	2000A (or as required at the connecting point)
3 second current (short circuit)	40kA (X/R 25) DC time constant 60ms { higher duties required at some locations usually < 63kA}
Operating Voltage (Transformer must accommodate the voltage range expected at the point of application)	325kV to 362kV 345kV nominal (typical "normal" voltages range from 345kV to 362kV)
RIV level @ 230 kV line to ground	300uV @1MHz
Lightning Impulse Withstand Voltage w/o line entrance	1300 kV
Lightning Impulse Withstand Voltage **With** line entrance arresters	1050 kV
Switching Impulse withstand level (20)	750kV
Typical Surge Arrester	209kV MCOV Station Class (258kV duty cycle)
Circuit Breaker line closing switching surge factor	2.2 (i.e. closing resistors required & no restrikes, or line end arresters used to clamp switching overvoltages.)
System Grounding	Effectively Grounded Neutral (always)
Lightning trip out Performance (station)	1/100years Keraunic level =40
Fault performance(circuit failure, including momentary) all other	1/40 years/breaker position

230kV Substation Electrical

Line Terminal & Equipment Continuous	To match connecting point or 2000A
3 second short circuit current	40kA (X/R=20) DC time constant 48ms { higher duties required at some locations usually < 63kA}
Operating Voltage (Transformer must accommodate this range)	220kV to 242kV 230kV nominal
Lightning Impulse Withstand Voltage	900kV BIL
Typical Surge Arrester	144kV MCOV Station Class (180kv Duty Cycle)
Lightning trip out Performance (station)	1/100 years Keraunic level =40
Fault performance (circuit failure, including momentary) all other	1/40 years/breaker position
System Grounding	Effectively Grounded Neutral (always)

138 kV Substation Electrical (new section)

Line Terminal & Equipment Continuous	To match connecting point or 2000A
3 second short circuit current	40 kA (X/R=20) DC time constant 48ms { higher duties required at some locations usually < 63 kA}
Operating Voltage (Transformer must accommodate this range)	131 kV to 145 kV 138kV nominal (*)
Lightning Impulse Withstand Voltage	650 kV BIL
Typical Surge Arrester	98 kV MCOV Station Class (120 kV Duty Cycle)
Lightning trip out Performance (station)	1/100years Keraunic level =40
Fault performance (circuit failure, including momentary) all other causes	1/40 years/breaker position
System Grounding	Effectively Grounded Neutral (always)

115 kV Substation Electrical

Line Terminal & Equipment Continuous	To match connecting point or 2000A
3 second short circuit current	40kA (X/R=20) DC time constant 48ms { higher duties required at some locations usually < 63kA}
Operating Voltage (Transformer must accommodate this range)	109 kV to 121 kV 115 kV nominal
Lightning Impulse Withstand Voltage	900kV BIL
Typical Surge Arrester	144kV MCOV Station Class (180 kv Duty Cycle)
Lightning trip out Performance (station)	1/100years Keraunic level =40
Fault performance (circuit failure, including momentary) all other	1/40 years/breaker position
System Grounding	Effectively Grounded Neutral (always)

69 kV Substation Electrical

Line Terminal & Equipment Continuous	To match connecting point or 2000A
3 second short circuit current	40kA (X/R=20) DC time constant 48ms { higher duties required at some locations usually < 63kA}
Operating Voltage (Transformer must accommodate this range)	66kV to 73 kV 69 kV nominal
Lightning Impulse Withstand Voltage	350 kV BIL
Typical Surge Arrester	57 kV MCOV Station Class (66 -72 kV Duty Cycle,)
Lightning trip out Performance (station)	1/100years Keraunic level =40 (recommended)
Fault performance (circuit failure, including momentary) all other	1/40 years/breaker position (recommended)
System Grounding	Effectively Grounded Neutral (always)

FUNCTIONAL CRITERIA:

When evaluating a proposed electrical interconnection the designated entity should 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, should 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 should be 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 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 an item of equipment will adversely impact adjacent equipment.
6. Consideration should 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. 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
    - Component reliability
    - Generator interface
    - Line Maintenance

- NERC, MAAC requirements/criteria
- Expandability/Adaptability
- Safety
- Changes in technology
- Cost (capital and O&M)
- Availability of spare equipment

Bus Configuration (From the SPP Min. Transmission Design Upgrades Doc. Dated May 2016)

Substations shall be designed using the bus configurations shown in the table below or as specified by SPP. All stations shall be developed to accommodate predicted growth and expansion (e.g., converting ring bus to a breaker and a half as terminals are added) throughout the anticipated planning horizon and as defined by SPP. For the purposes of this table, terminals are considered transmission lines, BES transformers, generator interconnections. Capacitor banks, reactor banks, and non-BES transformer connections are not considered to be a terminal.

Voltage (kV)	Number of Terminals	Substation Arrangement
100 - 200	One or Two	Single Bus
	Three to Six	Ring Bus
	More than Six	Breaker-and-a-half
201 - 765	One to Four	Ring Bus
	More than Four	Breaker-and-a-half

ACCESSABILITY AND LAYOUT:

Adequate space and firm vehicular surface must be provided on at least one side of each item of major electrical equipment to permit O&M vehicles, including bucket trucks and cranes, to access electrical equipment and to maneuver without requiring the de-energization of any adjacent electrical equipment in order to conduct maintenance or to remove and replace equipment. 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 must be provided.. For indoor GIS equipment a bridge crane may be used in lue 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 must 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 must be arranged with adequate clearances such that a catastrophic failure of equipment associated with one circuit would be unlikely to adversely affect equipment associated with another circuit.

A corridor, typically 15 – 25 feet in width, must be provided around the inside perimeter of the substation for vehicle movement. The corridor must be adequate for the weight of vehicles transporting the heaviest item of electrical equipment installed in the substation. If the corridor is required to be paved, it must meet this same functional requirement and might typically be constructed with a 6" crushed stone base covered with 4" of asphalt, which is covered with a 2" top layer of cover asphalt.

Twenty-four hours, unobstructed access must be provided for the substation. Typically asphalt paving is required from the driveway entrance to the relay/control house with parking for several vehicles. The entrance gate must be double roadway width with the yard's safety grounding covering the open gate area.

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

ABOVE GRADE PHYSICAL:

<u>Electrical Clearances (From the SPP Min. Transmission Design Upgrades Doc. Dated May 2016)</u>

All design and working clearances shall meet the requirements of the NESC. Additional vertical clearance to conductors and bus shall be provided in areas where foot and vehicular traffic may be present. Phase spacing shall meet IEEE C37.32 and NESC requirements.

Sufficient space to maintain OSHA minimum approach distances, either with or without tools, shall be provided. When live-line maintenance is anticipated, designs shall be suitable to support the type of work that will be performed (e.g., insulator assembly replacement) and the methods employed (i.e., hot stick, bucket truck work, etc.). This requirement is not intended to force working clearances on structures not intended to be worked from.

AC STATION SERVICE:

1. There must be two AC sources in which a single contingency cannot de-energize both the primary and back-up station services. An automatic throwover 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. Service reliability further categorizes loads as they are allocated to service panels with (essential loads) and without backup or alternate supplies and transfer switches. All equipment critical to the operation of the transmission facility should be provided with backup station service. This would include power transformers, breakers, SCADA, telecommunications, battery chargers, fire pumps, transmission cable oil pressure systems, motor-operated disconnect switches, etc. (Is this bullet needed?) – remove this bullet
4. Distribution lines shall not be used as a primary source.
5. Station service transformers shall be protected by surge arresters.
6. Emergency generators may be required where black start capability is required.
7. Due to the large 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.
8. All station service transformers shall have high side overcurrent protection (via a fuse or a bus protection scheme if the transformer is solidly connected to the bus).
9. Transfer switches may be installed internal or external to their associated switchboards, however, if they are located externally, they should 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 completed by separate cables are required for the supplies routed to the switch. (This needs more discussion.)
10. 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.
11. AC station service system components must be installed in accordance with manufacturer's instructions and applicable industry standards.
12. 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.
13. AC station service systems shall be physically arranged to facilitate safe and effective inspection and maintenance.

14. 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. 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.

    TSS will review the critical Transmission Facilities.

    Address PT installations on a ring bus configuration including primary and back-up.

Specification

1. As a minimum requirement, AC station service systems and equipment shall be designed for the purpose intended and shall support Clause II (Transmission System Design Criteria) 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 shall reflect this need.
3. Low side interrupting devices shall be breakers in the panels. Other isolation devices may be utilized such as fused disconnect switches. All devices shall be coordinated with each other to ensure proper protection.
4. All copper electrical contact parts and conducting mechanical joints shall be silver surfaced. Aluminum electrical contact parts and conducting mechanical joints shall be tin surfaced.
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 level digital signal circuits and analog signal circuits.
6. AC circuits shall be adequately sized and designed to limit voltage drop to no more than 5% continuous and 10% momentary.

STATIONARY BATTERIES AND CHARGERS:

1. Separate batteries for primary and back up protection are required and each battery must be fed by (1) independently supplied charger for stations 200KV and above. A battery with two independently supplied chargers is required at a minimum for stations less than 200kV.

2. 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 to be used.
3. Correction factors shall be included in battery sizing calculations to account for temperature conditions, battery aging and potential load increases.
4. Provisions must be made to facilitate the replacement of a failed charger or battery bank.
5. 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.

SPECIFICATION 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.

This Section must be reviewed by the DEDSTF Station Group

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 solar radiation.
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 are placed in service, appropriate acceptance testing shall be conducted and appropriate data, such as cell voltage and specific gravity, should be recorded for future use.
5. Battery and charger systems shall be adequately monitored and alarmed to assure that improper operation and abnormal conditions are reported for immediate corrective action.
6. Batteries shall be physically arranged to facilitate safe and effective inspection and maintenance.

This Section must be reviewed by the DEDSTF Station Group

DC STATION SERVICE

APPLICATION AND INSTALLATION of DC Station Service

1. When multiple battery and charger systems are provided to supply independent relay systems (often referred to as primary and backup or system one and system two), the DC distribution systems, including all associated wiring, should be kept physically and electrically separated to avoid problems with one system from affecting the other system.
2. DC station service system components should be installed in accordance with manufacturer's instructions and applicable industry standards.
3. All devices connected to the dc station service system should be capable of operating continuously and properly without malfunction or overheating in the voltage range specified by the designer of the system.
4. The output cables from the battery to the first breaker or protective device should be kept as short as possible; should be separately routed to reduce the possibility of a short circuit between the positive and negative cables; should be installed in non-metallic conduit to avoid grounding; and should be sized in consideration of the available dc short-circuit current from the battery.
5. DC station service systems must be adequately monitored and alarmed to assure that improper operation and abnormal conditions are reported for immediate corrective action.
6. DC station service systems should be physically arranged to facilitate safe and effective inspection and maintenance.

SPECIFICATION for DC Station Service

1. As a minimum requirement, DC station service systems and equipment should be designed for the purpose intended and should support Clause II (Transmission System Design Criteria) and be specified to meet the requirements of all applicable industry standards, including but not limited to ANSI, IEEE and NEMA.
2. This guide should be used in conjunction with the latest PJM Guide for the Design and Application of Stationary Batteries and Chargers for Transmission Facilities.
3. The typical nominal rating for this application is 125 volts.
4. The DC system design must take into consideration the voltage drop between the battery and the load terminals. 4% is typical for DC control systems.
5. The maximum load terminal voltage should not exceed the product of (the number of cells in battery) times (the maximum defined cell voltage).

MAINTENANCE

See section V.l.2.K for maintenance requirements.

GROUNDING:

Grounding and Shielding (From the SPP Min. Transmission Design Upgrades Doc. Dated May 2016)

The substation ground grid shall be designed in accordance with the latest version of IEEE Std. 80, Guide for Safety in AC Substation Grounding, using the fault currents defined in the Minimum Design Fault Current Levels section.

All bus and equipment shall be protected from direct lightning strikes using the Rolling Sphere Method. IEEE Std. 998, Guide for Direct Lightning Stroke Shielding of Substations.

Surge protection (with the appropriate energy rating determined through system studies) shall be applied on all line terminals and power transformers.

Southwest Power Pool, Inc.

Minimum Transmission Design Standards for Competitive Upgrades 12

RACEWAYS:

Design Considerations:

- Design of the raceway and conduit system shall be designed to accommodate all the anticipated station build out.
- 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 bundles.
- Long cable runs that parallel 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 withstand protection from vehicular and element protection.
- 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 utilizes a surface mounted trench system installation. No direct buried cable is 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 steel conduit shall be bonded.

Above Grade:

- All cable trays and junction boxes shall be grounded.
- Fiber shall be routed and protected either in its own separate tray and/ or conduit.

V.O RELAY AND CONTROL BUILDING REQUIREMENTS

1.0 GENERAL REQUIREMENTS

1.1 This document outlines the mechanical and electric requirements for relay and control buildings.

1.2 The building shall be suitably designed and constructed to contain all substation control and instrument panels, relay panels, metering panels, AC lighting and power panels, Annunicator, DFR, SCADA equipment, DC station batteries, DC Power Panels, battery chargers, toilet facilities (when required), office furniture, HVAC equipment, and local required telecommunications. 3rd party telecommunications equipment is not permitted to be installed in the control building, unless it is permitted by the Transmission Owner (TO). Consideration should shall be given to either sizing the building to accommodate the needs of the ultimate station development or to allow for the expansion for such accommodation.

1.3 Control Building is not to shall not be part of the Substation fence.

1.4 All materials and equipment used in the control building shall be noncombustibleto the greatest extent possible.

1.5 All internal equipment and devices are to be labeled as per the TO requirements.

2.0 SPECIFICATION

2.1 The building is toshall be designed and constructed in accordance with the latest revisions of all applicable national codes including but not limited to:

2.1.1 International Building Code (IBC) - Latest Edition

2.1.2 ASCE 7 - (American Society of Civil Engineers) – Minimum Design Loads for Buildings and Other Structures

~~2.1.3 AISC (American Institute of Steel Construction) Manual of Steel Construction - Latest Edition~~
~~2.1.4 NFPA (National Fire Protection Association) Codes - Latest Edition~~
~~2.1.5 NFPA 80 70 - NEC (National Electric Code) - Latest Edition (Refer to the NEC to determine what areas are applicable to these facilities)~~
~~2.1.6 IEEE C2 - NESC (National Electrical Safety Code)~~

2.1.1. ACI – American Concrete Institute
2.1.2. AISC – American Institute of Steel Construction
2.1.3. AISI – American Iron and Steel Institute
2.1.4. ANSI – American National Standards Institute
2.1.5. ASCE – American Society of Civil Engineers
2.1.6. ASTM – American Society for Testing and Material
2.1.7. AWS – American Welding Society
2.1.8. IBC – International Building Code
2.1.9. IEEE – Institute of Electrical and Electronics Engineers
2.1.10. MBMA – Metal Building Manufacturers Association
2.1.11. NESC – National Electrical Safety Code (IEEE C2)
NFPA – National Fire Protection Association
2.1.12. ~~2.1.7 And be in accordance with a~~All applicable state and local building codes and requirements.

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2.2 STRUCTURAL, ARCHITECTURAL AND MECHANICAL REQUIREMENTS

2.2.1 The building shall be ~~designed in accordance with (IBC) and~~ as specified below: ~~Building is to be sized to house all the necessary indoor equipment for the substation.~~

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

2.2.2 Building design loads shall include live, snow, wind, and dead loads. In addition, building 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.

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

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2.2.4~~3~~ 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 double door needs to be high enough to accept delivery of control and power panels (usually ≥ 8'-0" door height). A roll up garage door is acceptable in lieu of double doors.
2. Weather stripping shall be included around all edges.

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3. Means for locking and securing all doors shall be included, and door shall automatically lock upon closing.

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2.2.5~~4~~ Building ceiling and walls ~~to~~ shall be insulated. Vapor barriers ~~are to~~shall be provided.

2.2.6~~5~~ Gutters, downspouts, and splash block diffusers ~~may be required by the TO~~ shall be considered.

2.2.7~~6~~ ~~Typically, a minimum of two control cable entrances are recommended. Consideration should be given to designating one as a primary control cable entrance and the other as the secondary (back-up) entrance in order to promote a diverse routing practice for the relay and control cables. In addition, c~~Consideration ~~should~~ shall be given to separate cable entrances for the main and reserve AC station service feeders. Control cable entrances ~~are to~~ shall be sealed off to prohibit rodents from entering.

2.3 HEATING, COOLING, AND VENTILATION

2.3.1 ~~2.3.1~~ The building shall be equipped with sufficient heating, cooling ~~(if required by TO)~~, and ventilation equipment to provide acceptable ambient temperatures within the building so as not to impact the operation and life expectancy of the control equipment within.

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

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

2.4 ILLUMINATION

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

Ref. http://engineerboards.com/index.php?/topic/16992-nesc/

~~2.4.2 Interior lighting shall be properly designed for long life and low maintenance. utilizing 4' 0" fluorescent luminaries.~~

2.4.3 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, and should be sufficient for the safe and efficient operation of the equipment within.

> **Comment [P1]:** Is this a goal of emergency lighting?

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

2.4.5 Exit lights ~~are to~~shall be provided in accordance with local codes. These lights may be required to be connected to the emergency lighting circuit.

2.5 GROUNDING

2.5.1 Structural building 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 NEC and NESC.

2.5.2 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.

2.5.3 Cable tray system shall be provided with a continuous run of copper wire for grounding purposes. Cable to be bonded to cable ladder system at a minimum of once per cable ladder section.

Comment [P2]: Should we include this?

3.0 APPLICATION & SPECIAL CONSIDERATIONS

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3.1 RACEWAYS

3.1.1 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~~, per the preference of the TO~~. Raceways are to be suspended from building ceiling. Cable tray shall be aluminum or galvanized steel construction ~~(per the TO preference)~~ and be sized adequately for anticipated cable loads. Mechanical protection may be needed on vertical raceway sections to a height of 7’-0” in high traffic areas.

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

3.2 WORKING SPACE

3.2.1 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.

3.2.2 A desk and Filing cabinet should be ~~provided~~ considered for operational support purposes.

3.3 SAFETY EQUIPMENT

3.3.1 Signage as required by ~~the~~ 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.

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

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

3.3.4 Provisions for containing acid spillage from the control battery ~~should~~ shall be included in design of the facility. ~~Shielding may be required by TO.~~

3.4 SECURITY

3.4.1 Security monitoring ~~may be required (consult with Transmission Owner)~~ shall be properly designed and operated per applicable regulatory requirements.

Comment [P3]: Cover under general security section?

3.5 PLUMBING AND TOILET FACILITIES ~~(if required by TO)~~

3.5.1 If required, shall~~Must~~ be in accordance with all applicable local building codes and requirements.

~~3.6 DC REQUIREMENTS~~

~~3.6.1 Refer to the appropriate section of the **PJM TSDS TSS Technical Transmission Owner Guidelines Requirements** on the PJM web site. See section **PJM Design and Application of V.J. Substation Batteries and Chargers**, and Section **PJM Design and Application of V.K. DC Station Service**~~

~~3.7 AC REQUIREMENTS~~

~~3.7.1 Refer to the appropriate section of the **PJM TSS Transmission Owner Guidelines TSDS Technical Requirements** on the PJM web site. See section **PJM Design and Application V.I. AC Station Service**~~

3.8 METERING, SYSTEM PROTECTION, ANNUNICATOR, DFR, SCADA, AND TELECOMMUNICATIONS

3.8.1 For specific information and details pertaining to protection design schemes, relaying requirements, under frequency relaying requirements, SCADA requirements, etc. see the ~~**Protective Relaying Philosophy and Design GuidelinesStandards, as prepared and posted by the PJM Relay Subcommittee**~~**<insert DEDSTF Relay reference>**, as well as consulting with the incumbent TO.

3.8.2 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 voltage rises. ~~A telephone is required.~~

3.8.3 Free standing or rack mounted panels are acceptable.

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

STRUCTURAL:

Structural Design Loads (From the SPP Min. Transmission Design Upgrades Doc. Dated May 2016)

Structures, insulators, hardware, bus, and foundations shall be designed to withstand the following combinations of gravity, wind, ice, conductor tension, fault loads, and seismic loads (where applicable). The magnitude of all weather-related loads, except for NESC or other legislated loads shall be determined using the 100 year mean return period and the basic wind speed and ice with concurrent wind maps defined in the ASCE Manual of Practice (MOP) 113. The load combinations and overload factors defined in ASCE MOP 113 or a similar documented procedure shall be used.

Line Structures and Shield Wire Poles (From the SPP Min. Transmission Design Upgrades Doc. Dated May 2016)

• NESC Grade B, Heavy Loading
• Other legislated loads
• Extreme wind applied at 90 degrees to the conductor and structure
Southwest Power Pool, Inc.
Minimum Transmission Design Standards for Competitive Upgrades 11
• Extreme wind applied at 45 degrees to the conductor and structure
• Ice with concurrent wind
• Extreme ice loading, based on regional weather studies

Equipment Structures and Shield Poles without Shield Wires (From the SPP Min. Transmission Design Upgrades Doc. Dated May 2016)

• Extreme wind, no ice
• Ice with concurrent wind
• Forces due to line tension, fault currents and thermal loads

In the above loading cases, wind loads shall be applied separately in three directions (two orthogonal directions and at 45 degrees, if applicable).

Structure and Foundation Design (From the SPP Min. Transmission Design Upgrades Doc. Dated May 2016)

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

• ASCE Standard No. 10, Design of Latticed Steel Transmission Structures
• ASCE Standard No. 48, Design of Steel Transmission Pole Structures
• ASCE Standard No. 113, Substation Structure Design Guide
• AISC 360 Specification for Structural Steel Buildings
• ACI 318 Building Code Requirements for Structural Concrete and Commentary

Deflection of structures shall be limited such that equipment function or operation is not impaired, and that proper clearances are maintained. The load combinations, overload factors, and deflection limits defined in ASCE MOP 113 or a similar documented procedure shall be used.

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

RATING GUIDES:

Rating of Bus Conductors (From the SPP Min. Transmission Design Upgrades Doc. Dated May 2016)

The minimum amperage capability of substation bus conductors shall meet or exceed the values shown below, unless otherwise specified by SPP. If otherwise specified by SPP, the SPP value shall govern. The amperage values shown in the table shall be considered to be associated with emergency operating conditions.

The emergency rating is the amperage that the circuit can carry for the time sufficient for adjustment of transfer schedules, generation dispatch, or line switching in an orderly manner with acceptable loss of life to the circuit involved. Conductors shall be selected such that they will lose no more than 10 percent of their original strength due to anticipated periodic operation above the normal rating.

Voltage (kV)	Emergency Rating (Amps)
100 - 200	~~1,2~~2,000
230	2,000
345	3,000
500	3,000
765	4,000

Normal circuit ratings shall be established by the Respondent such that the conductor can operate continuously without loss of strength. Consideration shall be given to electrical system performance (voltage, stability, losses, impedance, corona, and audible noise), and for the effects of the high electric fields when selecting the size and arrangement of phase conductors and sub-conductors.

For bare, stranded conductors, the conversion from conductor ampacity to conductor temperature shall be based on IEEE Publication No. 738, Standard for Calculating the Current-Temperature Relationship of Bare Overhead Conductors, SPP Criteria 12.2.2, or other similar documented approaches.

For rigid bus conductors, the conversion to conductor operating temperature shall be based on IEEE Std. 605, Guide for Bus Design in Air Insulated Substations, SPP Criteria 12.2.2 as applicable, or other similar documented approaches."