Minimum Transmission Design Standards for Competitive Upgrades Rev 2

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Minimum Design Standards Task Force

Southwest Power Pool

Revision History

Date or Version Number	Author	Change Description	Comments
12/17/2014 Revision IR	MDSTF	Original	Approved by MDSTF and PCWG
1/23/2015 Revision 1	MDSTF	Changed the 230 kV rating in the transmission circuit design to 1,200 amps minimum in table on page 8	Changed per MOPC request and approved by MDSTF
6/23/2016	MDSTF	Edits Face-to-face Meeting	
9/22/16	MDSTF	Edits per WebEx	
12/6/2016	MDSTF	Webex meeting changes as per RCWG review.	Final version for PCWG and MOCP approval

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Acronyms and Definitions

ACI	American Concrete Institute
ADSS	All-Dielectric Self Supporting
AISC	American Institute of Steel Construction
AISI	American Iron and Steel Institute
ANSI	American National Standards Institute
ASCE	American Society of Civil Engineers
BIL	Basic Insulation Level
CFR	Code of Federal Regulation
CIGRE	International Council on Large Electric Systems
CT	Current Transformers
CVT	Capacitive Voltage Transformer
DETC	De-energized Tap Changer
DME	Disturbance Monitoring Equipment
DTT	Direct Transfer Trip
FAC	Facilities Design, Connections, and Maintenance
FAC-008	Facility Ratings Methodology
GPS	Global Positioning System
IEC	International Electrotechnical Commission
IEDs	Intelligent Electronic Devices
IEEE	Institute of Electrical and Electronics Engineers
LTC	Load Tap Changer
MOP	Manual of Practice
MTDS	SPP Minimum Transmission Design Standards
NEMA	National Electrical Manufacturers Association
NERC	North American Electric Reliability Corporation
NESC	National Electrical Safety Code
OLTC	On-Load Tap Changer Transformer
OPGW	Optical Ground Wire
OSHA	Occupational Safety & Health Administration
PLC	Power Line Carrier
PMU	Phasor Measurement Unit
RFP	Request for Proposal
PT	Potential Transformer
RTU	Remote Terminal Unit
SCADA	Supervisory Control and Data Acquisition
TO	Transmission Owner
TOSP	Transmission Owner Selection Process
TPL	Transmission Planning
VAR	Volt Ampere Reactive

Introduction

Applicability

A Request for Proposal ("RFP") shall be published for each Competitive Upgrade approved for construction by the SPP Board of Directors after January 1, 2015. Competitive Upgrades are subject to the Transmission Owner Selection Process ("TOSP") set forth in Section III of Attachment Y of the SPP Open Access Transmission Tariff ("SPP Tariff") and associated SPP Business Practices.

SPP shall issue an RFP for a Competitive Upgrade to solicit proposals from Qualified RFP Participants or QRPs, as defined in Attachment Y of the SPP Tariff, ("Respondent"). These SPP Minimum Transmission Design Standards ("MTDS") outline the minimum design standards to be used by the Respondent in its response to such RFP issued by SPP pursuant to the TOSP for Competitive Upgrades. If there is a conflict between the RFP and MTDS, the RFP shall govern what the Respondent shall use in its RFP Response. If there is a conflict between the RFP and the SPP Tariff or Business Practices, the SPP Tariff and Business Practices shall govern.

The MTDS represent the minimum design standards by which a Competitive Upgrade must be designed by the successful Respondent unless the project approved by the BOD and set forth in the RFP specifies different values than those provided in the MTDS. The MTDS facilitate the design of transmission facilities in a manner that is compliant with NERC requirements and SPP Criteria; are consistent with Good Utility Practice, as defined in the SPP Tariff[1]; and are consistent with current industry standards specified herein, such as NESC, IEEE, ASCE, CIGRE, and ANSI, at the time the RFP is issued.

Individual sections within this document contain minimum design standards for transmission lines and transmission substations. If the Respondent has questions regarding the MTDS or the RFP design requirements, it is the Respondent's sole responsibility to direct such questions to the SPP in the manner specified by SPP in the RFP. SPP bears no responsibility if the Respondent does not understand the MTDS or RFP design requirements. The Respondent is encouraged to clarify such questions prior to the RFP Response due date allowing time for SPP to address such questions.

[1] The SPP Tariff defines Good Utility Practice as follows: "Good Utility Practice: Any of the practices, methods and acts engaged in or approved by a significant portion of the electric utility industry during the relevant time period, or any of the practices, methods and acts which, in the exercise of reasonable judgment in light of the facts known at the time the decision was made, could have been expected to accomplish the desired result at a reasonable cost consistent with good business practices, reliability, safety and expedition. Good Utility Practice is not intended to be limited to the optimum practice, method, or act to the exclusion of all others, but rather to be acceptable practices, methods, or acts generally accepted in the region, including those practices required by Federal Power Act section 215(a)(4)."

Respondents should provide sufficient information supporting their design to the Industry Expert Panel so that it can be used in the evaluation of the RFP Response.

Any RFP Response submitted to SPP in the TOSP that exceeds the RFP design requirements is submitted solely at the discretion of the Respondent and should include supporting information.

All references to standards contained herein through reference mean standards as of the date the project was initially approved by the SPP BOD.

Transmission Lines

General

Transmission lines shall be designed to meet all applicable federal, state, and local environmental and regulatory requirements.

Electrical Clearances

Design clearances shall meet the requirements of the NESC. To account for survey and construction tolerances, a minimum design margin of 2 feet shall be applied to ensure the NESC clearances are maintained after construction. This margin shall be applied to conductor-to-ground and conductor-to-underlying or –adjacent object clearances, but need not be applied to conductor-to-transmission structure clearances. These clearances shall be maintained for all NESC requirements and during the ice with concurrent wind event as defined in the *Structure Design Loads Section*. In regions susceptible to conductor galloping, phase-to-phase and phase-to-shield wire clearances during these conditions shall be considered.

Sufficient space to maintain OSHA minimum approach distances in place at the date of project approval, 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, or helicopter work, etc.).

Structural Design Loads

All structure types (deadends, tangents, and angles), insulators, hardware, and foundations shall be designed to withstand the following combinations of gravity, wind, ice, conductor tension, construction, and maintenance loads. The magnitude of all weather-related loads, except for NESC or other legislated loads shall be determined using a 100 year mean return period and the basic wind speed and ice with concurrent wind maps defined in the ASCE Manual of Practice (MOP) 74. With the exception of the NESC or other legislated loads that specify otherwise, overload factors shall be a minimum of 1.0.

Loads with All Wires Intact

- NESC Grade B, Heavy Loading
- Other legislated loads
- Extreme wind applied at 90º to the conductor and structure
- Extreme wind applied at 45º to the conductor and structure

- Ice with concurrent wind
- Extreme ice loading

Unbalanced Loads (applies to tangent structures only)

- Longitudinal loads due to unbalanced ice conditions, considering 1/2''radial ice, no wind in one span, no ice on adjacent span, with all wires intact at 32º Fahrenheit final tension. This load case does not apply to insulators; however, insulators must be designed such that they do not detach from the supporting structure.
- Longitudinal loads due to one broken ground wire or one phase position (the phase may consist of multiple sub-conductors). For single conductor phases, use 0" ice, 70 mph wind, 0º F and for multi-bundled phases use no wind, 60º F. Alternatively, for lines rated below 200 kV, provide stop structures at appropriate intervals to minimize the risk of cascading failures. This load case does not apply to insulators; however, insulators must be designed such that they do not detach from the supporting structure.

Construction and Maintenance Loads

- Construction and maintenance loads shall be applied based on the recommendations of *ASCE MOP 74.*

Structure and Foundation Design

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

- *ASCE Standard No. 10, Design of Latticed Steel Transmission Structures*
- *ASCE Standard No. 48, Design of Steel Transmission Pole Structures*
- *ASCE Manual No. 91, Design of Guyed Electrical Transmission Structures*
- *ASCE Manual No. 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. 751, Trial-Use Design Guide for Wood Transmission Structures*
- *ACI 318 Building Code Requirements for Structural Concrete and Commentary*

Proper clearances with design margins shall be maintained under deflected structure conditions.

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

Insulation Coordination, Shielding, and Grounding

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

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

Phase Conductors

The minimum amperage capability of phase 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 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	1,200
230	1,200
345	3,000
500	3,000
765	4,000

The conversion from conductor ampacity to conductor temperature shall be based on SPP Planning Criteria 7.2.; however, the RFP will specify the design wind speed and direction.

Shield Wire

Fiber shall be installed on all new transmission lines being constructed, consisting of OPGW, underground fiber, or ADSS fiber. Where there are multiple shield wires and OPGW is utilized, only one need be OPGW. The shield design shall be determined based on the anticipated fault currents generating from the terminal substations.

Adequate provisions shall be made for fiber repeater redundancy as well as power supply redundancy at each repeater.

The minimum number of fiber strands per cable shall be 36.

Reactive Compensation

Final reactive compensation shall be provided as specified by SPP.

Transmission Substations

Substation Site Development

Transmission substations shall be sited and designed to meet all applicable environmental and regulatory requirements. Each shall be developed to accommodate the intended electrical purpose. Sufficient property shall be provided to accommodate predicted growth and expansion throughout the anticipated planning horizon and as defined in the RFP. The final size shall consider future maintenance and major equipment replacement needs.

The design and development of the substation property shall be completed with due consideration to the existing terrain and geotechnical conditions. Storm water management plans and structures must comply with all federal, state, and local regulations. The substation pad shall be graded such that it is at or above the 100-year flood level, however alternate methods such as elevating equipment may be considered by SPP.

Electrical Clearances

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.

Structural Design Loads

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

- NESC Grade B, Heavy Loading

- Other legislated loads
- Extreme wind applied at 90 degrees to the conductor and structure
- 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

- 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

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.

Grounding and Shielding

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.

Bus Design

Substation bus shall be designed in accordance with *IEEE Std. 605, Guide for Bus Design in Air Insulated Substations and ASCE Manuel 113.*

Bus Configuration

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

Rating of Bus Conductors

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	2,000
230	2,000
345	3,000
500	3,000
765	4,000

For bare, stranded conductors, the conversion from conductor ampacity to conductor temperature shall be based on SPP Planning Criteria 7.2; however, the RFP will specify the design wind speed and direction.

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. The RFP will specify the design wind speed and direction.

Substation Equipment

All substation equipment should be specified such that audible sound levels at the edge of the substation property are appropriate to the facility's location.

Minimum Basic Insulation Levels (BIL)

Substation insulators, power transformer windings and bushings, potential transformer bushings, current transformer bushings, and power PTs shall meet the minimum BIL levels shown in the tables below. When placed in areas of heavy contamination (coastal, agricultural, and industrial), extra-creep insulators, special coatings to extra-creep porcelain insulators, or polymer insulators shall be used.

Substation Insulators

Nominal System L-L Voltage (kV)	BIL (kV Crest)	BIL (kV Crest) Heavy Contaminated Environment
115 - 138	550	650 (Extra Creep)
161	650	750 (Extra Creep)
230	750	900 (Extra Creep)
345	1050	1300 (Extra Creep)
500	1550	1800 (Standard Creep)
765	2050	2050 (Standard Creep)

Power Transformers, Potential Transformers and Current Transformers

Nominal System L-L Voltage (kV)	Power Transformer Winding BIL (kV Crest)	Power PTs (kV Crest)	PT and CT BIL (kV Crest)	Circuit Breaker BIL (kV Crest)
115	450	550	550	550
138	550	650	650	650
161	650	650	650	650
230	750	900	900	900
345	1050	1300	1300	1300
500	1425	N/A	1550 / 1800	1800
765	2050	N/A	2050	2050

Power Transformers

Power transformers shall comply with the latest revisions of ANSI/IEEE C57, NEMA TR-1, and IEC 76. NEMA TR-1 shall apply only to details not specified by ANSI/IEEE C57, and IEC shall apply to details not specified by ANSI/IEEE C57 or NEMA TR-1.

For transformers with low voltage winding below 200kV, On-Load Tap Changing transformers (OLTC) shall be equipped with automatically and manually operated "tap-changing-under-load" equipment. This shall have a range of 10% above and below the rated low voltage in 32 steps (33 positions). The LTC shall allow the tertiary voltage where applicable to follow the high side voltage throughout the entire tap range (i.e., the effective HV-TV turns ratio shall remain constant within 0.5%).

De-energized Tap Changing (DETC) transformers shall have five high voltage full capacity taps designed for operation with the unit de-energized.

Minimum Design Fault Current Levels

Substations shall be designed to withstand the calculated available symmetrical fault current including predicted growth and expansion throughout the anticipated planning horizon. Design values will be determined from system models provided by SPP.

Minimum Rating of Line Terminal Equipment

Terminal definition – point of demarcation between the transmission line and the substation. The transmission line terminal shall be considered the substation deadend structure.

Terminal Equipment definition – All equipment located within the substation that is considered, for ratings purposes, to be a part of the transmission line. This equipment consists of jumpers, devices, switches, bus, etc., through which line current flows to the common substation bus.

The minimum amperage capability of substation terminal equipment shall meet or exceed the rating of the associated transmission line, unless otherwise specified by SPP. If otherwise specified by SPP, the SPP value shall govern.

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. Equipment shall be rated in accordance with SPP Planning Criteria 7.2.

Substation Service

Two sources of AC substation service, preferred and backup shall be provided. This shall be accomplished by using the tertiary winding of an autotransformer, power PTs connected to the bus, distribution lines or a generator. Distribution lines shall not be used as a primary source unless no other feasible alternative exists. Generators shall not be used as a primary source.

Control Enclosures

Control enclosures shall be designed to the requirements of the applicable publications:

- *ASCE 7, Minimum Design Loads for Buildings and Other Structures*
- *AISC 360 Specification for Structural Steel Buildings*
- *AISI Specification for the Design of Cold-Formed Steel Structural Members*
- *ACI 530/530.1, Building Code Requirements and Specification for Masonry Structures and Related Commentaries*
- *ACI 318, Building Code Requirements for Structural Concrete and Commentary*
- *NESC*
- *OSHA*

Design loads and load combinations shall be based on the requirements of the *International Building Code* or as directed by the jurisdiction having authority. Weather loads shall be based on a 100 year mean return period.

Wall and roof insulation shall be designed in accordance with the latest edition of the *International Energy Conservation Code* for the applicable Climate Zone.

Oil Containment

Secondary oil containment shall be provided around oil-filled electrical equipment and storage tanks in accordance with the requirements found in 40 CFR 112 of the United States EPA and local ordinances.

Metering

Intertie metering shall be installed in accordance with SPP Planning Criteria 8.9 and the Interconnect Agreement with the incumbent Transmission Owner(s) (TOs). Metering criteria should match those of the connected TO and Transmission Operator.

Transmission Protection and Control Design

General

Substation protection and control equipment must adhere to *SPP Criteria*, and be compatible with the incumbent TO standards. It is the responsibility of the successful Respondent to contact the incumbent TO(s) to ensure proper coordination of both the communication channel and the relay systems

For all new substations, all Intelligent Electronic Devices (IEDs) shall be synchronized through the use of a satellite GPS clock system.

Communication Systems

Power Line Carrier (PLC) equipment, microwave, or fiber may be used on existing transmission lines consistent with existing in-service technology. PLC shall not be used for lines less than 5 miles due to the reliability characteristics of the equipment. Fiber protection schemes shall be used for all new transmission lines.

Voltage and Current Sensing Devices

For primary and secondary protection schemes, independent current transformers (CTs) and independent secondary windings of the same voltage source shall be used.

CTs used for relaying shall be C800 with a thermal rating factor of 2.0 or greater.

CVTs and wound PTs used in relaying shall be designed and tested to meet all applicable ANSI and NEMA standards. CVTs and wound PTs shall have a minimum accuracy class of CL 1.2 WXYZ for relaying and CL 0.3 WXYZ for metering.

DC Systems

For new substations greater than 200 kV, redundant battery systems shall be installed.

At all voltage levels, battery system(s) of sufficient capacity to support station requirements for a minimum duration of 8 hours without AC power shall be installed..

Primary and Secondary Protection Schemes

Primary and secondary protection schemes shall be required for all lines and be capable of detecting all faults on the line. The primary scheme shall provide communications-assisted, high-speed simultaneous tripping of all line terminals at speeds that will provide fault clearing times for system stability as defined in the most recent version of the *NERC Transmission Planning and Reliability Standards (TPL)*.

The following criteria shall be used to determine if one or two high speed protection systems are required on a line. While it is possible that the minimum protective relay system and redundancy requirements outlined below could change as *NERC Planning and Reliability Standards* evolve, it will be the responsibility of the Respondent to assess the protection systems and make any necessary modifications to comply with these changes.

Line Applications

General

Alarms shall be provided for loss of communication channels and relay failure.

Automatic check-back features shall be installed on PLC-based protection schemes using) on/off carrier to ensure the communication channel is working properly at all substations.

Local breaker failure protection shall be provided for all breakers.

765 kV / 500 kV

At least two high speed pilot schemes using a redundant battery design, dual direct transfer trip (DTT), and redundant communication paths are required. . Power Line Carrier requires Mode 1 coupling (three phase coupling).

230 kV/345 kV

Dual high speed communications-assisted schemes using a redundant battery design, one direct transfer trip (DTT), and redundant communication paths are required. Dual DTT systems are required for direct equipment protection (reactors or series capacitors)..

Below 230 kV

A minimum of one high speed communications-assisted scheme is required.

Single phase coupling for PLC is acceptable. Breaker failure DTT system is required if remote clearing time is not acceptable based on the TPL assessment. Dual pilot schemes may be required for proper relay coordination or system dynamic performance requirements. When dual high speed systems are needed, redundant communication paths shall be used. Dual DTT systems are required for direct equipment protection (reactors or capacitors).

Transformer Applications

High Voltage Winding Above 200 kV

Transformer protection shall be designed with a redundant station battery configuration, with the protection divided into two systems using redundant overlapping zones of protection. Each system must provide differential protection schemes and have independent lockout function. Also, at least one system must provide backup overcurrent protection, and sudden pressure alarm or tripping.

High Voltage Winding 100 kV to 200 kV

Transformer protection shall be designed with the protection divided into two systems using redundant overlapping zones of protection. Each system must provide differential protection schemes and have independent lockout function. Also, at least one system must provide backup overcurrent protection, and sudden pressure alarm or tripping.

Bus Applications

200 kV and Above

Bus protection shall be designed using a redundant station battery configuration with the protection divided into two systems. Each system must provide differential protection schemes and have independent lockout function.

Below 200 kV

Bus protection shall be designed with the protection divided into two systems. Each system must provide differential protection schemes and have independent lockout function.

Other Substation Equipment

For substation devices, such as capacitor banks, static VAR compensators, reactors, etc., appropriate protection systems shall be incorporated.

Sync Potential and Sync Scopes

Sync potential sources (wire wound PTs or CCVTs) and synchronizing equipment shall be installed consistent with incumbent TO's requirements.

Disturbance Monitoring Equipment (DME)

DME shall be installed in accordance with current NERC PRC-002 requirements.

Phasor Measurement Units (PMUs)

PMU capability through the use of Intelligent Electronic Devices (IEDs) or other devices capable of providing PMU measurements, shall be installed in all new substations above 200 kV. One or more PMU capable devices at each voltage level above 100 kV within the substation shall be provided.

SCADA and RTUs

SCADA and RTUs shall be installed in all substations. Points and protocols should match those of the connected TO and Transmission Operator.