MINIMUM TRANSMISSION DESIGN STANDARDS FOR COMPETITIVE UPGRADES

REVISION 3

Minimum Design Standards Task Force

10/12/2021

3.0

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	
9/22/2016	MDSTF	Edits per WebEx	
12/6/2016, Revision 2	MDSTF	Webex meeting changes as per RCWG review.	Final version for PCWG and MOCP approval
10/12/2021, Revision 3	MDSTF	Revised to improve RFP process	Approved by MOPC

CONTENTS

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
BES	Bulk Electric System
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 Reliability Standards
FAC-008	Facility Ratings Methodology Reliability Standard
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 Reliability Standards
VAR	Volt Ampere Reactive

1 INTRODUCTION

1.1 APPLICABILITY

A Request for Proposal ("RFP") will 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 will 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 will govern what the Respondent will 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 will govern.

The MTDS represent the minimum design standards by which a Competitive Upgrade shall 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 facilitates 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 shall 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.

1.2 WORD USAGE[2]

The word *shall* indicates mandatory requirements strictly to be followed in order to conform to the standard and from which no deviation is permitted (*shall* equals *is required to*).

The word *should* indicates that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others; or that a certain course of action is preferred but not necessarily required (*should* equals *is recommended that*).

The word *may* is used to indicate a course of action permissible within the limits of the standard (*may* equals *is permitted to*).

The word *can* is used for statements of possibility and capability, whether material, physical, or causal (*can* equals *is able to*).

The word *will* is used for statements of fact.

[2] The Word Usage section comes from Section 1.3 of the IEEE SA Style Manual and was reprinted with permission from IEEE.

2 TRANSMISSION LINES

2.1 GENERAL

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

2.2 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.).

2.3 STRUCTURAL DESIGN LOADS

All transmission line components shall be designed to resist the effects of all load cases described in Sections 2.3.1 through 2.3.4. Transmission line components include structures, insulators, hardware, and foundations.

2.3.1 NESC AND OTHER LEGISLATED LOADS

The design strength of all transmission line components shall fully comply with all appropriate provisions of the NESC and any other legislated code or rule required by the authority having jurisdiction.

The SPP territory is located in both the NESC Heavy and Medium Loading Districts. The Rules for the Loading District in which the line is located shall apply. For lines located in both the Medium and Heavy Loading Districts, the Rules for the Heavy Loading District shall apply. All lines shall be designed using Grade B Construction.

2.3.2 EXTREME WEATHER EVENTS

Transmission line components shall be capable of resisting the following extreme weather events. Overload factors shall be a minimum of 1.0. Note these load requirements are in addition to the NESC or any other legislated load requirements.

- Extreme wind applied in the direction causing the most unfavorable effect, but at a minimum at an angle of 90° and 45° to the wires and structure.
- Ice with concurrent wind, with the wind applied in the direction causing the most unfavorable effect, but at a minimum at an angle of 90° and 45° to the wires and structure.

The magnitude of the extreme wind load, and the ice with concurrent wind load shall be selected based on a 100-year mean return interval. The corresponding loads shall be determined using the ASCE Manual of Practice (MOP) 74, *Guidelines for Electrical Transmission Line Structural Loading*. A minimum of Exposure Category C is required.

2.3.3 UNBALANCED LOADS

The following two unbalanced load cases shall be applied to all tangent structures and associated components.

- 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 32° Fahrenheit final tension. This load case does not apply to insulators; however, insulators shall 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, 0° F and for multi-bundled phases use no wind, 60° 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 shall be designed such that they do not detach from the supporting structure.

2.3.4 CONSTRUCTION AND MAINTENANCE LOADS

Construction and maintenance loads shall be applied based on the recommendations of *ASCE MOP 74*. Overload factors shall be a minimum of 1.0.

2.4 STRUCTURE AND FOUNDATION DESIGN

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

- ASCE Standard 10, *Design of Latticed Steel Transmission Structures*
- ASCE Standard 48, *Design of Steel Transmission Pole Structures*

- ASCE Manual of Practice 91, *Design of Guyed Electrical Transmission Structures*
- ASCE Manual of Practice 104, *Recommended Practice for Fiber-Reinforced Polymer Products for Overhead Utility Line Structures*
- ASCE Manual of Practice 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.

2.5 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.

2.6 RATING OF PHASE CONDUCTOR

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

The emergency rating is the ampacity 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.

Phase Conductor Emergency Ratings

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 IEEE 738, *Standard for Calculating the Current-Temperature Relationship of Bare Overhead Conductors*. The RFP will specify the design wind speed, wind direction, ambient air temperature, absorptivity, emissivity, and time of day. The Respondent is responsible for determining the value of the remaining parameters.

2.7 LINE LOSSES

Line losses shall be calculated using 50 percent of the emergency rating. The emergency rating shall be the value stated in the table shown in the "Phase Conductor" section (above).
When determining the line impedance, the ambient air temperature shall be 25°C.

2.8 SHIELD WIRE AND FIBER REQUIREMENTS

Transmission lines shall be adequately shielded for lightning protection. The shield wire shall be sized based on the anticipated fault currents generating from the terminal substations. When transmission line projects tie into existing substations, the anticipated fault currents will be provided in the RFP.

Where a fiber communication path is required, the minimum number of fiber strands shall be 36 in each cable. Fiber may be either OPGW, underground fiber cable, or ADSS fiber cable.

Where redundant fiber communication paths are required for protection systems, the use of multiple fibers within a single OPGW, underground fiber cable, or ADSS fiber cable is not an acceptable redundant path. A separate OPGW, underground fiber cable, or ADSS fiber path, is required to establish a redundant path.

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

When the incumbent TO standards exceed the requirements of this document, those requirements will be provided in the RFP.

2.9 REACTIVE COMPENSATION

The need for reactive compensation will be determined by SPP following award of the RFP.

3 TRANSMISSION SUBSTATIONS

3.1 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. 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 shall 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.

3.2 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 Std. C37.32, *American National Standard for High Voltage Switches, Bus Supports, and Accessories Schedules of Preferred Ratings, Construction Guidelines, and Specifications* 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.

3.3 STRUCTURAL DESIGN LOADS

All substation components shall be designed to resist the effects of all load cases described in Sections 3.3.1 through 3.3.3. Substation components include structures, insulators, bus, hardware, and foundations.

3.3.1 NESC AND OTHER LEGISLATED LOADS

The design strength of all substation components shall fully comply with all appropriate provisions of the NESC and any other legislated code or rule required by the authority having jurisdiction.

The SPP territory is located in both the NESC Heavy and Medium Loading Districts. The Rules for the Loading District in which the station is located shall apply. All line-supporting structures shall be designed using Grade B Construction.

3.3.2 EXTREME WEATHER EVENTS

Substation components shall be capable of resisting the following extreme weather events. The load combinations and overload factors defined in ASCE Manual of Practice (MOP) 113, *Substation Structure Design Guide*, or a similar documented procedure shall be used. Note these load requirements are in addition to the NESC or any other legislated load requirements.

- Extreme wind applied in the direction causing the most unfavorable effect, but at a minimum at an angle of 90° and 45° to the wires/bus and structure.
- Ice with concurrent wind, with the wind applied in the direction causing the most unfavorable effect, but at a minimum at an angle of 90° and 45° to the wires/bus and structure.
- Extreme ice loading

The magnitude of the extreme wind load, and the ice with concurrent wind load shall be selected based on a 100-year mean return interval. The corresponding loads shall be determined using ASCE MOP 113. A minimum of Exposure Category C is required.

3.3.3 OTHER LOADS

Fault current and thermal loading shall be used in the design of substation components as applicable.

3.4 STRUCTURE AND FOUNDATION DESIGN

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

- ASCE Standard 10, *Design of Latticed Steel Transmission Structures*
- ASCE Standard 48, *Design of Steel Transmission Pole Structures*
- ASCE Manual of Practice 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 shall be used.

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

3.5 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 Section 3.12 and the RFP.

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

Surge protection (with the appropriate energy rating determined through system studies) shall be provided for line terminals, power transformers, and other major equipment as required by IEEE Std. C62.22, *Guide for Application of Metal-Oxide Surge Arresters for Alternating Current Systems*.

3.6 BUS DESIGN

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

3.7 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) as defined by SPP. For the purposes of this table, terminals are considered transmission lines, BES transformers, and generator interconnections. Capacitor banks, reactor banks, and non-BES transformer connections are not considered to be a terminal.

Bus Configurations

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

3.8 RATING OF BUS CONDUCTOR

The minimum ampacity 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 ampacity shown in the table shall be considered to be associated with emergency operating conditions.

The emergency rating is the ampacity 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.

Bus Conductor Emergency Ratings

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 IEEE 738, *Standard for Calculating the Current-Temperature Relationship of Bare Overhead Conductors*. The RFP will specify the design wind speed, wind direction, ambient air temperature, absorptivity, emissivity, and time of day. The Respondent is responsible for determining the value of the remaining parameters.

For rigid bus conductors, the conversion from conductor ampacity to conductor temperature shall be based on IEEE Std. 605, *Guide for Bus Design in Air Insulated Substations*. The RFP will specify the design wind speed, wind direction, ambient air temperature, absorptivity, emissivity, and time of day. The Respondent is responsible for determining the value of the remaining parameters.

3.9 SUBSTATION EQUIPMENT

All substation equipment should be specified such that audible sound levels at the edge of the substation property comply with local noise requirements.

3.10 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
161	650	750
230	750	900
345	1050	1300
500	1550	1800
765	2050	2050

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

3.11 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 windings 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.

3.12 MINIMUM DESIGN FAULT CURRENT LEVELS

Substations shall be designed to withstand the calculated available symmetrical fault current including predicted growth and expansion. Design values will be provided in the RFP.

3.13 OWNERSHIP DEMARCATION

The ownership Point-of-Demarcation for conductors, shield wires, fiber optic cables, and any other line components, between a transmission line and a substation, for two different Transmission Owners will be specified in the RFP.

3.14 MINIMUM RATING OF LINE TERMINAL EQUIPMENT

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 ampacity 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 ampacity 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.

3.15 SUBSTATION SERVICE

Two sources of AC substation service, primary 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.

3.16 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.

3.17 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.

3.18 METERING

Intertie metering shall be installed in accordance with SPP Integrated Marketplace Protocols, Appendix C and the Interconnect Agreement with the incumbent Transmission Owner(s) (TOs). Metering criteria should match those of the connected TO and Transmission Operator.

4 TRANSMISSION PROTECTION AND CONTROL DESIGN

4.1 GENERAL

New substations that are Competitive Upgrades subject to the TOSP shall comply with the requirements set forth below.

For transmission lines which connect to terminal substations owned by incumbent TO(s), the protection and control will be designed in accordance with the standards and practices of the incumbent TO(s). The incumbent TO requirements will be provided in the RFP. It is the responsibility of the successful Respondent to ensure proper installation coordination of both the communication channel and the relay systems with the incumbent TO(s).

Substation protection and control equipment shall adhere to *NERC PRC* and *TPL* Standards and this document.

All Intelligent Electronic Devices (IEDs) shall be synchronized with a satellite GPS clock system.

4.2 COMMUNICATION SYSTEMS

Fiber shall be provided as the communication path for the primary protection system for all new transmission lines. Fiber may be either OPGW, underground fiber, or ADSS.

Where redundant communication paths are required for protection systems, the use of multiple fibers within a single OPGW, underground fiber cable, or ADSS fiber cable is not an acceptable redundant path. A separate OPGW, underground fiber cable, or ADSS fiber path, is required to establish a redundant path.

Power Line Carrier (PLC), microwave, or fiber are all acceptable methods for the redundant communication path for communications-assisted protection systems. PLC shall not be used for lines less than 5 miles.

4.3 VOLTAGE AND CURRENT SENSING DEVICES

For primary and secondary protection schemes, independent current transformers (CTs) and independent secondary windings of the same voltage source 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 have a minimum accuracy class of CL WXYZ for relaying.

4.4 DC SYSTEMS

For new substations greater than 200 kV, redundant DC systems shall be installed. A redundant system requires two completely independent DC systems, each comprised of batteries, battery chargers, and trip circuits. Each DC system shall be capable of meeting the entire DC load requirement of the substation.

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.

4.5 PRIMARY AND SECONDARY PROTECTION SCHEMES

Primary and secondary protection schemes shall be included 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 criteria described in Sections 4.5.1 through 4.5.4 shall be used to determine whether one or two high-speed protection systems are required. 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.

4.5.1 LINE APPLICATIONS

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.

The table on the next page provides more detail for line protection requirements.

Transmission Line Protection Requirements

	765 kV	500 kV	345 kV	230 kV	< 230 kV
Primary Requires High Speed Communication Assisted Pilot Scheme	Yes	Yes	Yes	Yes	Yes
Secondary Requires High Speed Communication Assisted Pilot Scheme	Yes	Yes	Yes	Yes	No [1]
Direct Transfer Trip for Line	Dual	Dual	Single	Single	Not Required
Direct Transfer Trip for Equipment Attached to Line (reactors, series capacitors, etc.)	Dual	Dual	Dual	Dual	Dual
Primary Scheme Communication Path	Fiber [2]	Fiber [2]	Fiber [2]	Fiber [2]	Fiber [2]
Secondary Scheme Communication Path	Fiber, Microwave, PLC	Fiber, Microwave, PLC	Fiber, Microwave, PLC	Fiber, Microwave, PLC	N/A [3]
PLC Coupling	Three Phase (Mode 1)	Three Phase (Mode 1)	Single Phase	Single Phase	Single Phase
Redundant DC System Required [4]	Yes	Yes	Yes	Yes	No[5]

Table Notes:

1) Required in some instances for proper relay coordination or system dynamic performance requirements. It is the responsibility of the Respondent to assess the need.
2) The primary fiber path shall be fiber (OPGW, ADSS, or underground) installed on the protected line where available.
3) If the secondary scheme requires a communication path it may be fiber, microwave, or PLC.
4) A redundant DC system includes dual batteries, battery chargers, and trip circuits. Each DC system shall be capable of meeting the entire DC load requirement of the substation.
5) Unless required by the most recent version of NERC TPL Standards.

4.5.2 TRANSFORMER APPLICATIONS

For transformers with high voltage windings above 200kV, 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 shall provide differential protection schemes and have independent lockout function. In addition, at least one system shall provide backup overcurrent protection, and sudden pressure alarm or tripping.

For transformers with high voltage windings between 100kV and 200kV, protection shall be designed with the protection divided into two systems using redundant overlapping zones of protection. Each system shall provide differential protection schemes and have independent lockout function. In addition, at least one system shall provide backup overcurrent protection, and sudden pressure alarm or tripping.

4.5.3 BUS APPLICATIONS

For buses 200kV and above, protection shall be designed using a redundant station battery configuration with the protection divided into two systems. Each system shall provide differential protection schemes and have independent lockout function.

For buses between 100kV and 200kV, protection shall be divided into two systems. Each system shall provide differential protection schemes and have independent lockout function.

4.5.4 OTHER SUBSTATION EQUIPMENT

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

4.6 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.

4.7 DISTURBANCE MONITORING EQUIPMENT (DME)

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

4.8 PHASOR MEASUREMENT UNITS (PMUs)

PMU capability through the use of Intelligent Electronic Devices (IEDs) or other devices capable of providing PMU measurements, shall be provided for each BES voltage in all new substations above 200kV. The installation of associated communication infrastructure is not required.

4.9 SCADA AND RTUs

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