BONNEVILLE POWER ADMINISTRATION

Bulk Electric System Facility Ratings Methodology
STD-D-000011

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Submitted	Concurred	Approved
Richard A Becker Vincent L. Lemelli, Jr.	Harold H. Gruppe	Lloyd S. Hill

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1. INTENT

This standard provides the current BPA rating methodology for the following Bulk Electric System (BES) Facilities as defined in the NERC Glossary of Terms dated August 2, 2006:

- Transmission Lines
- Transformers
- Static VAR Compensators
- Shunt Reactive Compensation including Shunt Capacitors and Shunt Reactors
- Series Reactive Compensation including Series Reactors and Series Capacitors
- Protection & Control Settings

This standard applies to facilities solely owned by BPA and facilities jointly owned for which BPA has responsibility for providing ratings. It is intended to provide documentation in compliance with NERC Reliability Standard FAC-008-3, *Facility Ratings,* approved by NERC Board of Trustees and applicable at time of publication of STD-D-000011, latest revision, consistent with effective date of FAC-008-3.

2. DEFINITIONS

Based on NERC Glossary of Terms Used in Reliability Standards and terminology applicable to facility ratings used in NERC Standards and explanatory documentation.

Ampacity: The current carrying capability of equipment or a facility element at a specific operating temperature.

Component: This term is frequently used in NERC documentation and for the purpose of using the term component in this BPA standard it is considered synonymous with the term equipment.

Element: NERC Definition - Any electrical device with terminals that may be connected to other electrical devices such as a generator, transformer, circuit breaker, bus section, or transmission line. An element may be comprised of one or more components.

Equipment: An individual subcomponent of an element of the BES. As an example, a circuit breaker with current transformers connected to protective relaying would be a facility element with relay and current transformer equipment. For the purpose of using the term equipment used in this BPA standard it is considered synonymous with the term component as used in NERC documentation.

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Equipment Rating: NERC Definition - The maximum and minimum voltage, current, frequency, real and reactive power flows on individual equipment under steady state, short-circuit and transient conditions, as permitted or assigned by the equipment owner.

Facility: NERC Definition - A set of electrical equipment that operates as a single Bulk Electric System Element (e.g., a line, a generator, a shunt compensator, transformer, etc.).

Facility Rating: NERC Definition - The maximum or minimum voltage, current, frequency, or real or reactive power flow through a facility that does not violate the applicable equipment rating of any equipment comprising the facility.

Facility Rating Limitation: The facility rating is limited by the most limiting equipment rating.

Operating Limitations: Operating limit of equipment including temporary de-rating of impaired equipment in accordance with good utility practice.

Transmission Line: BPA transmission lines are defined as those transmission circuits that terminate at fault interrupting circuit breakers. These lines may have one or more conductor types or sizes, bundle configurations, connector types, substations, line taps (generation insertion or load serving), or step up/down power transformer(s) in the line between breakers. The physical line between substations, line taps, and between locations of conductor size or type, bundle configuration, and connector type transitions are termed “transmission line sections.”

3. BACKGROUND

BPA bases its rating methodology on industry standards, original equipment manufacturer (OEM) ratings, and for transmission lines, a probabilistic electrical clearance analysis as discussed below. The facilities addressed in this document are comprised of various electrical equipment or elements (as defined by NERC). BPA facilities may contain one or more equipment types or elements. For example, a transmission line may include conductors, line traps, switches, breakers and protective relays. Since the limits for any facility must first be defined at the individual equipment level, this document organizes the equipment into two major categories, Substation Equipment and Transmission Line Equipment.

As required by NERC reliability standard FAC-008-3, each Facility Rating shall respect the most limiting applicable Equipment Rating of the individual equipment that comprises that Facility.

3.1 Revision History

- Revision 02 (Current Revision), 8/9/2013: Clarified various items, added references, and general edits.
- Revision 01, 6/27/12: Combined FAC-009 and FAC-011 into one document and updated various items.

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- Revision 00, 3/28/11: Initial approval of standard. This standard supersedes document, BPA Bulk Electric System Facilities Rating Methodology, Revision dated April 07, 2008 and document FAC 9 Facility Rating Methodology, Revision dated August 11, 2010. Reliability Standard FAC-008-3 combines currently effective standards FAC-008-1 and FAC-009-1 into a single standard and replaces both of these superseded standards on the effective date of 01/01/2013. For more information, refer to NERC Docket No. RD11-10-000.

4. POLICY AND APPLICATION

4.1 BPA Facility Ratings Methodology - Process Overview

The overall process for setting, documenting, and applying the BPA Facility Ratings Methodology is described in this section.

Equipment ratings are set by BPA's Engineering & Technical Services organization. Substation equipment ratings are determined by the Substation Maintenance and High Voltage Engineering group (TESM) according to the standards in Section 4.2 below. Electrical data and associated Normal Ratings are documented in the BPA System Electrical Data Book (SED). Transformer ratings are further detailed in the BPA Transformer Loading Guide.

Transmission Line ratings are determined by the Transmission Line Design group (TELC) using their By-Line rating application according to the standards in Section 4.3 below. Electrical data and Normal Ratings for transmission lines are documented in the SED.

4.1.1 *Modified Branch Elements*

As transmission system additions and modifications are planned, any transmission system element that is identified as changing is tagged as a modified transmission branch element. Once tagged, the element rating is determined by Engineering & Technical Services. New electrical data and revised ratings are conveyed to the Communications & Grid Modeling group (TPM) and the Technical Operations group (TOT) by memo. The Communications and Grid Modeling group posts the revised electrical data in the SED and updates the branch data in the study databases. The Technical Operations group consolidates the Facility Rating information into a "bottleneck report" which serves as a tool for both Dispatch and TPM. See Figure 1.

Facility Ratings are based on normal operating topology as specified for the applied seasonal temperature and location in the NW region. The Facility Ratings note the most limiting element as associated to the transmission element and how it is modeled for the associated application. This includes any transformer limit (if applicable), and associated circuit breaker(s).

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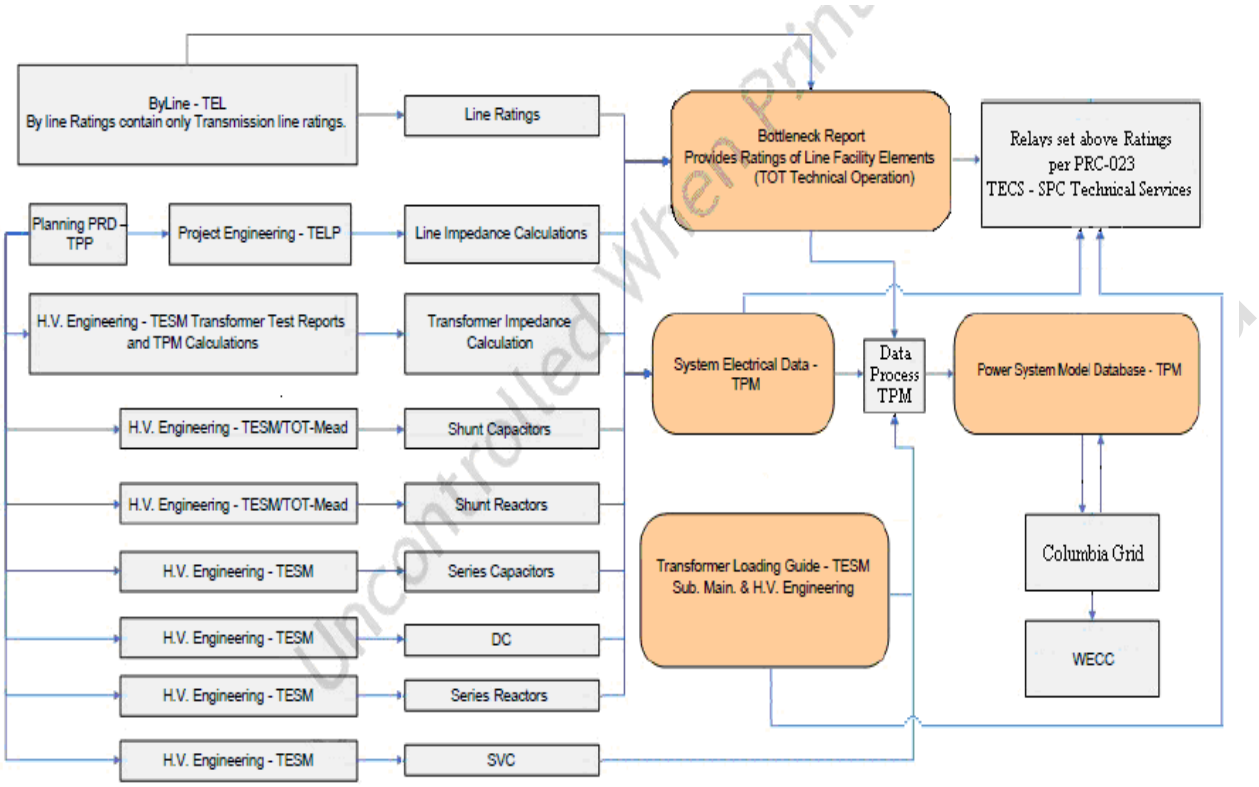

Figure 1.--- Establish and Communicate Facility Ratings Flow Chart

Details on how the Facility Ratings data is treated in BPA Base Cases are described in Appendix A through C.

4.2 Substation Equipment, Elements, and Facility Ratings

Rated substation equipment includes power transformers; instrument transformers; shunt reactors; series reactors; power circuit breakers; disconnect switches; circuit switchers; shunt capacitors; series capacitors; thyrister-controlled series capacitors; static VAR compensators; DC terminal; line traps; and bus conductors, fittings, and attachments.

In some cases, substation equipment is combined together into transmission elements. Methodology for determining the element rating from the included equipment ratings is given in the sections below, where element ratings apply.

In more limited cases, substation equipment and/or elements are combined together into BES Facilities which are, in turn, modeled in planning and operational studies, using the Facility Ratings. The methodology for determining the substation equipment/element ratings for the Facility Ratings is described in the sections below.

4.2.1 *Power Transformers*

4.2.1.1 Power Transformer Equipment Ratings

BPA power transformer ratings are maintained in the SED and Transformer Loading Guide that include the nameplate rating in MVA (megavolt-amperes), and the Summer Emergency and Winter Emergency ratings, also in MVA. The Emergency Ratings are determined by the following methods:

- Application of Standard IEEE C57.91, Guide for Loading Mineral-Oil Immersed Power Transformers. BPA uses an Excel based program to produce a loading guide for each transformer, listing ratings for normal and emergency conditions. The spreadsheet is based on the methodology from the IEEE standard.
- "PT-Load" computer program developed by Electric Power Research Institute (EPRI). This program utilizes the algorithms in the above IEEE C57.91 loading guide. BPA uses this program to evaluate special conditions (mostly short-term conditions) that fall outside of the standard loading guides discussed under the first bullet above.
- Limitations of the transformer bushings are established based on the original bushing manufacturer information and bushing nameplate rating. BPA's specifications require that the bushings are <u>not</u> the limiting factor to load a transformer.

Continuous thermal limits are set based on not exceeding the rated transformer temperatures. Operating within these limits should ensure normal transformer life.

Emergency limits above the continuous thermal limits are set based on acceptance of a shortening transformer life for unusual occurrences. The emergency limits are the following:

- Extra loss-of-insulation-life is limited to 0.5% per week with a total period not to exceed 4 weeks per year.
- The transformer hottest-spot temperature shall not to exceed 130 degrees C.
- The maximum loading is limited to 150% of maximum nameplate rating.

4.2.1.2 <u>Power Transformer Element Ratings</u>

The power transformer element rating is set at the most limiting rating among the power transformer and associated current transformers and buswork. However, BPA ensures that current transformers and buswork are always sized so as not to limit full-rated operation of the power transformer. Therefore, the power transformer element rating is equal to the power transformer equipment rating.

4.2.1.3 <u>Power Transformer Facility Ratings</u>

Power transformer Facility Ratings are set at the level of the most limiting equipment/element rating among the power transformer and the associated circuit breakers, disconnect switches, and/or circuit switchers.

4.2.2 *Instrument Transformers*

4.2.2.1 <u>Instrument Transformer Equipment Ratings</u>

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Instrument transformers include voltage transformers, potential devices, and current transformers. The following instrument transformers are used on the BPA transmission system:

- Voltage Transformers and Potential Devices

Free standing voltage transformers and potential devices, including metering units, are specified and rated according to:

  - IEEE C57.13, IEEE Standard Requirements for Instrument Transformers, for Protection and Metering applications.

Voltage transformers and potential devices are not limiting elements. They are not current-carrying components, so load ratings do not apply.

- Current Transformers

Free standing current transformers, including metering units, are specified and rated according to:

  - IEEE C57.13, IEEE Standard Requirements for Instrument Transformers, for Protection and Metering applications
  - IEEE C57.13.6, IEEE Standard for High Accuracy Instrument Transformers, for Metering with High Accuracy and Extended Range applications

BPA has standardized metering current transformers as follows:

a. 500 kV and 230 kV with rating factor of 2: 2000:5 ratio, with accuracy of 0.15% and extended range (1.6 amp to 4000 amps primary current).
b. 115 kV and 69 kV with rating factor of 2: 1000:5 ratio, with accuracy of 0.15% and extended range (0.8 amp to 2000 amps primary current).
c. 15 kV to 34.5 kV with rating factor of 1.5: 1000:5 ratio, with accuracy of 0.30% and extended range (10 amps to 1500 amps primary current).

BPA rates transmission instrument transformers according to the manufacturer's specifications with nominal ratings shown on the nameplate. BPA operates instrument transformers at the normal transmission rating, therefore the Emergency Ratings of instrument transformers are identical to the Normal Ratings. BPA maintains a stock of standardized rating instrument transformers for normal use and for emergencies.

4.2.2.2 Instrument Transformer Element and Facility Ratings

BPA selects instrument transformers sized to allow full-rated operation of their associated circuit elements. Therefore, BES Facility Ratings are not limited by instrument transformer ratings. Consequently, element and Facility Ratings do not apply to instrument transformers.

4.2.3 *Shunt Reactors*

4.2.3.1 Shunt Reactor Equipment Ratings

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Shunt reactors on the Bulk Electric System are specified and rated according to:

- IEEE C57.21, IEEE Standard Requirements, Terminology, and Test Code for Shunt Reactors Rated Over 500 kVA

4.2.3.2 Shunt Reactor Element and Facility Ratings

Shunt reactors in support of the Bulk Electric System are specified, designed and applied for the full range of system voltage conditions and ranges to which they will be subjected. The Normal Rating for BPA shunt reactors is provided on the manufacturer's nameplate. Shunt reactor loading is controlled by the voltage applied to the terminals. Overloading under emergency conditions is not applicable because they are shunt devices (connected line-to-ground). Consequently, element and Facility Ratings do not apply to shunt reactors.

4.2.4 *Series Reactors*

4.2.4.1 Series Reactor Equipment Ratings

Transmission series connected reactors are specified and rated according to:

- IEEE C57.16, IEEE Standard Requirements, Terminology, and Test Code for Dry-Type Air-Core Series-Connected Reactors

Transmission series reactors are rated per the manufacturer's specifications. The Normal Rating for BPA transmission series reactors is given on the manufacturer's nameplate. BPA does not provide ratings above normal for series reactors. Therefore, no Emergency Ratings are provided as they would be equal to the Normal Ratings.

4.2.4.2 Series Reactor Element and Facility Ratings

BPA applies series reactors as current limiting reactors (CLR) for reducing short circuit fault current at station busses and transmission lines in addition to switching transients on shunt capacitor facilities. They are rated, designed, and applied to accommodate the full range of system voltage and current conditions to which they will be subjected, plus with capability above the rating of the equipment they are connected to such that they will not be a limiting element of the facility they are part of. Consequently, Facility Ratings do not apply to series reactors.

4.2.5 *Circuit Breakers*

4.2.5.1 Circuit Breaker Equipment Ratings

AC high-voltage circuit breakers are rated and specified by operating voltage, continuous current, interrupting current, and operating time. BPA rates power circuit breakers according to the manufacturer's specifications. The Normal Rating for BPA power circuit breakers is as shown on the manufacturer's nameplate. Power circuit breakers are rated, specified, and applied according to the following standards and associated applicable corrigendum or amendments in affect on the date the power circuit breaker was designed:

- ANSI/IEEE C37.04, Rating Structure for High-Voltage Circuit Breakers

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- ANSI/IEEE C37.06, Standard for Switchgear - AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis - Preferred Ratings and Related Required Capabilities for Voltages Above 1000 V.
- ANSI/IEEE C37.06.1, High–Voltage Circuit Breakers Rated on Symmetrical Current Basis Designated – Definite Purpose for Fast Transient Recovery Voltage Rise Times
- ANSI/IEEE C37.09, Test Procedure for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis.
- ANSI/IEEE C37.010, Application Guide for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis
- ANSI/IEEE C37.011, Application Guide for Transient Recovery Voltage for AC High Voltage Circuit Breakers
- ANSI/IEEE C37.11, Requirements for Electrical Control for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis
- NEMA SG 4, High-Voltage Circuit Breakers
- IEC 62271-100-2008 High-voltage switchgear and controlgear - Part 100: Alternating current circuit-breakers (Annex N)

Nameplate interrupting ratings are adjusted for reclosing of oil circuit breakers per ANSI/IEEE C37.04, IEEE Standard Rating Structure. Ratings above normal for power circuit breakers are determined according to the above referenced standards and any associated applicable corrigendum or amendments in affect on the date installed or reviewed.

4.2.5.2 Circuit Breaker Element Ratings

The circuit breaker element rating is set at the most limiting rating among the power circuit breaker and associated current transformers and buswork.

4.2.5.3 Circuit Breaker Facility Ratings

Circuit breakers are not modeled as stand-alone facilities.

4.2.6 *Disconnect Switches*

4.2.6.1 Disconnect Switch Equipment Ratings

BPA rates transmission disconnect switches for both normal and emergency operation according to the manufacturer's specifications and IEEE C37.37 loading guides.

The following standards are used to rate high-voltage switches:

- IEEE C37.30, IEEE Standard Requirements for High-Voltage Switches.
- IEEE C37.37, IEEE Standard Loading Guide for AC High-Voltage Switches (in excess of 1000 volts).

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- IEEE C37.37a, IEEE Standard Loading Guide for AC High-Voltage Air Switches Under Emergency Conditions.

4.2.6.2 Disconnect Switch Element and Facility Ratings

Disconnect switch element and Facility Ratings are equal to disconnect switch equipment ratings.

4.2.7 *Circuit Switchers*

4.2.7.1 Circuit Switcher Equipment Ratings

- AC high-voltage circuit switchers (CS) are rated and specified by operating voltage, continuous current, interrupting current, and operating time.

BPA rates transmission circuit switchers according to the manufacturer's specifications. The Normal Rating for BPA transmission circuit switchers is as shown on the manufacturer's nameplate. Circuit switchers are rated, specified, and applied according to the following standards and associated applicable corrigendum or amendments in affect on the date the circuit switcher was designed:

- ANSI/IEEE C37.06, AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis - Preferred Ratings and Related Required Capabilities for Voltages Above 1000 V
- ANSI/IEEE C37.010, Application Guide for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis
- ANSI/IEEE C37.016, AC High-Voltage Circuit Switchers rated 15.5 kV through 245 kV
- ANSI/IEEE C37.11, Requirements for Electrical Control for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis

Ratings above normal for circuit switchers are determined according to the above referenced standards and any associated applicable corrigendum or amendments in affect on the date installed or reviewed.

4.2.7.2 Circuit Switcher Element Ratings

The circuit switcher element is set at the most limiting rating between the circuit switcher and associated current transformers and buswork.

4.2.7.3 Circuit Switcher Facility Ratings

Circuit switchers are not modeled as stand-alone facilities.

4.2.8 *Shunt Capacitors*

4.2.8.1 Shunt Capacitor Equipment Ratings

Transmission shunt capacitors at BPA are specified and rated according to:

- IEEE Std. 18, IEEE Standard for Shunt Power Capacitors
- IEEE Std. 1036, IEEE Guide for the Application of Shunt Power Capacitors

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- IEEE C37.99, IEEE Guide for the Protection of Shunt Capacitor Banks

Transmission shunt capacitors are specified, designed and applied for the full range of normal system voltage and environmental conditions. This includes ratings beyond nameplate that are provided in the national standards or by the manufacturer of the equipment. The Normal Rating for BPA transmission shunt capacitors are provided by the equipment manufacturer. Short time ratings beyond nameplate are also provided by the manufacturer and not less than that identified in the national standards.

As part of normal dispatch of shunt capacitor banks, when the voltage exceeds the target voltage, the bank would be removed from service. As such, BPA does not have ratings above normal (which includes continuous and short time capabilities) for shunt capacitor banks. Therefore, no Emergency Ratings are provided as they would be equal to the Normal Ratings.

4.2.8.2 Shunt Capacitor Element and Facility Ratings

Other associated power system equipment connected to the bank such as breakers, switches, bus work and relay settings are designed not to be limiting elements for the operation of the bank. Therefore the shunt capacitor bank equipment ratings become the limiting ratings of the shunt capacitor facility.

Planning and Operations are provided with the normal and short time capability of the facility and use this information to plan and dispatch the system.

4.2.9 *Series Capacitors*

4.2.9.1 Conventional Series Capacitor Equipment Ratings

Transmission series connected capacitors are specified and rated according to:

- IEEE Std. 824 - 2004, IEEE Standard Requirements for Series Capacitors in Power Systems.
- IEEE C37.116, Guide for Protection Relaying Applications to Transmission Connected Series Capacitors.

Transmission series capacitors are specified, designed and applied for the full range of normal system voltage, currents and environmental conditions. The Normal Rating for BPA transmission series capacitors are provided on the manufacturer's nameplates and instruction books. These ratings are consistent with power system requirements and provide a normal (continuous) and a 30 minute rating. System swing and transient capabilities are carefully coordinated with system requirements at each individual location.

4.2.9.2 Conventional Series Capacitor Element and Facility Ratings

On new installations, other associated power system equipment connected to the series capacitor such as breakers, switches, bus work and relay settings are designed not to be limiting elements for the operation of the series capacitor. Therefore the series capacitor ratings become the limiting ratings of the series capacitor facility. Where the banks are upgraded, the short time rating of other devices may be limiting.

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Planning and Operations are provided with the normal, emergency and swing capability of the facilities and use this information to plan and dispatch the system.

4.2.9.3 Thyristor Controlled Series Capacitor (TCSC) Equipment Rating

Transmission TCSC is specified and rated according to:

- IEEE Std. 1534 – 2002 Recommended Practice for Specifying TCSC

Slatt TCSC was developed and installed as part of an EPRI R&D project prior to the publication of IEEE Std. 1534. The bank MVAR range and allowable currents were reviewed and approved by BPA, EPRI and GE and are described in Instruction Book Volume 1 Section 1. Following a number of thyristor failures, GE (the equipment vendor) re-evaluated the bank ratings. As presently configured, each of the 6 modules is capable of 1.33 ohms capacitive for a total of 8 ohms nominal or 2 ohms and a total of 12 ohms when in vernier mode. The current ratings are 2900 A continuous, 4350 A for 30-min, and 5800 A for 10-sec. GE has provided a figure showing the complex relationship between TCSC reactance, line current and various protective thresholds. When bypassed the bank is 1.2 ohm inductive.

4.2.9.4 Thyristor Controlled Series Capacitor (TCSC) Element and Facility Ratings

Other associated power system equipment connected to the Slatt TCSC such as bypass breakers, bypass and isolating switches, buswork and relay settings are designed not to be limiting elements for the operation of the TCSC. Therefore, the TCSC equipment ratings become the limiting ratings of the element and facility.

4.2.10 *Static VAR Compensators*

4.2.10.1 Static VAR Compensator Equipment Ratings

Transmission class Static VAR Compensators (SVCs) are specified and rated according to:

- IEEE Std. 1031 - 2000, Guide for the Functional Specification for Transmission Static VAR Compensators.

Transmission class SVCs are specified, designed and applied for the full range of normal system voltage conditions and ranges to which they will be subjected. Harmonic impedance data and existing harmonic content is also considered when specifying an SVC. The Normal Rating for BPA transmission class SVCs is per the manufacturer's nameplate. BPA SVCs are specified with some over and under voltage capability depending on the application, and therefore possess some emergency ratings depending on the desired performance and intended purpose.

4.2.10.2 Static VAR Compensator Element and Facility Ratings

Other associated power system equipment connected to the SVC, such as breakers, switches, buswork and relay settings are designed not to be limiting elements for the operation of the device. Therefore the SVC ratings become the limiting ratings of the SVC Element and Facility.

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4.2.11 *High Voltage Direct Current Converter Terminal (Northern Terminal of Pacific HVDC Intertie) Equipment, Element and Facility Ratings*

The capacity of the Pacific HVDC Intertie has been dictated by technologic capability of HVDC equipment and the power transfer requirements between the Pacific Northwest and Pacific Southwest over the life of the DC Intertie. The HVDC Terminal and all associated equipment are rated and assembled as an integrated Facility. HVDC equipment and element ratings are designated by the manufacturer and incorporated into the over-all facility ratings provided by the converter vendor. The converter terminal is fully automatic and dynamically controls operation under normal and emergency system conditions. Protections from abnormal conditions are fully automatic and an integral part of the converter controls preventing the converter terminal facility from exceeding voltage or current capabilities. The converter process is self-regulating and will not exceed rated operating limitations, and these operating limitations are the Facility Rating.

4.2.11.1 Industry Standards

ANSI/IEEE Std 1030 – 1987 “IEEE Guide for Specification of High-Voltage Direct-Current Systems Part I – Steady State Performance.

IEC-60700-1 Testing of Semiconductor Valves for High Voltage DC Power Transmission

IEC 60919-1 Performance of High Voltage DC System

IEEE 857-1996 Recommended Practice for Test Procedures for High-Voltage Direct-Current Thyristor Valves

IEC-61803 Determination of losses in HVDC converter stations

4.2.11.2 Normal Facility Rating Criteria

The maximum HVDC power transfer cannot exceed the ability of the supporting AC networks at each end. 1) The West Coast power grid must be able to remain electrically stable under a Pacific HVDC Intertie bipolar loss at all DC power flows, 2) the AC grid/connection at each DC end must be able to thermally support the DC flow, and 3) the AC grid/connection must be strong enough to maintain a stable waveform with low distortion so that accurate valve firing can take place.

4.2.11.3 Emergency Facility Rating Criteria

DC emergency load ratings are based on the line capacity and the converter equipment capacity. These are developed at the time of procurement of the DC equipment and are based on such factors as expected ambient temperature, cooling capacity, thermal characteristics of the thyristors, transformers, and other equipment, and also the equipment-purchasing-customer’s (BPA) desired overload rating.

4.2.12 *Line Traps*

4.2.12.1 Line Trap Equipment Rating

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Line traps are parallel L-C resonant circuits with the inductance in series with the coupled phase of the line to provide high impedance to a carrier signal and minimal impedance at 60Hz line current. This inductance is rated to match the BIL, through current capability and short-circuit withstand capability of any other major equipment on the line. Reference Document:

- ANSI C93.3, Requirements for Power-line Carrier Line Traps.

The Normal Rating for BPA line traps are as shown on the manufacturer's nameplate. BPA does not have ratings above normal for line traps, therefore, no Emergency Ratings are provided as they would be equal to the Normal Ratings.

4.2.12.2 Line Trap Element and Facility Ratings

BPA assures that Line Traps are always sized so as not to limit full-rated operation of their associated circuit elements, therefore, BES facility ratings are not limited by Line Trap ratings.

4.2.13 *Bus Conductors, Fittings and Attachments*

The ampacity rating of buswork is based on its ability to dissipate heat and the allowable temperature rise above the ambient temperature. BPA uses IEEE Std. 605 methodology for determining bus ampacity and the industry standard Design Temperature of 30°C above a 40°C ambient for a total conductor temperature of 70°C. Based on a set of assumptions and generalizations specific to BPA's service territory, tables have been developed for nominal bus current ratings. These can be found in *BPA Bus and Bus Fittings Standard*, STD-DS-000013.

Standard bus nominal current ratings have been established in STD-DS-000013 to cover the majority of all needs of bus work at BPA. Depending on conditions, the ampacities may be increased with the proper technical evaluation. Non-standard ratings may be applied permanently or for emergency conditions only, per the BPA standard.

4.3 **Transmission Line Equipment, Element, and Facility Ratings**

Transmission line facilities are comprised of three main elements: transmission line conductors, within-line switching equipment, and substation terminal equipment. Ratings for substation terminal equipment and within-line switching equipment are addressed in the Substation Equipment, Elements, and Facility Ratings Section, Section 4.2.

4.3.1 *Overhead Transmission Line Conductor Equipment Ratings*

4.3.1.1 Normal Thermal Line Rating Criteria (Conductor Temperature 50C -100C)

Normal Thermal Line Ratings and associated amperages for overhead transmission lines and line sections are based upon the following methodology: A or B, and C, D, and E.

A. Solely upon BPA or contract line design packages (which incorporate BPA probabilistic design buffers. See STD-DT-000014, *Required Content of a*

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Transmission Line Design and Construction Package for further information related to design packages), and construction quality assurance by BPA or contract construction inspection prior to energizing.

Follow-up electrical clearance analysis (deterministic and/or probabilistic based upon data sources employed) is performed on the design package or on an as-built PLS-CADD LiDAR Model.

B. An electrical clearance analysis is performed which may incorporate a probabilistic analysis in addition to a deterministic analysis to NESC requirements, depending upon the data sources employed. The probabilistic analysis is a BPA processes specific three standard deviation, Gaussian distribution analysis resulting in an approximate 99.9% confidence level of meeting NESC clearances in the field.

- Reference:
  - o BPA's Probability Based Clearance Buffers

    Part I: General Development

    Part ll: Application to the Design of New Lines

    Part III: Application to the Analysis of Existing Lines
  - o Electrical Clearance Analysis Data Sources

    1. New lines, rebuilds, and large re-conductors and upgrades typically employ line design and LiDAR profile data within the PLS-CADD analysis platform.

    2. Small re-conductors, upgrades, and re-rates typically employ line design data and existing survey or re-surveyed profile data within either the BPA legacy or PLS-CADD analysis platform; may employ design data and LiDAR data within PLS-CADD; or may employ combinations thereof depending on the data available.

    3. BPA verification of field conditions pursuant to NERC Recommendations will typically employ post construction LiDAR data within the PLS-CADD analysis platform, but may employ other data forms updated by manual means (e.g., annual TLM and helicopter patrols and/or manual resurveying).

C. Amperage ratings are based upon electrical clearance analyses results and IEEE 738 Steady State Heat Transfer Analyses as well as connector amperage limitations.

D. Continuous operation at rated amperages based upon maximum rated conductor temperature that satisfies NESC clearance requirements and ensures safe and reliable facility operation. These ratings serve as the normal, full-time, continuous ratings for the line and/or line sections.

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E. The single amperage rating for a transmission line element comprised of more than one line section between fault interrupting circuit breakers is the limiting amperage of the line sections that comprise the transmission line element.

4.3.1.2 Elevated Temperature Thermal Line Rating Criteria (Conductor Temperature 100C -200C)

Elevated temperature thermal line ratings for overhead transmission lines are infrequently applied at BPA. In all cases where elevated temperature ratings are employed, the same criteria as discussed under Normal Thermal Line Rating criteria is utilized, except that the conductor maximum temperatures are in accordance with the values specified under "Maximum elevated conductor operating temperatures." Under the elevated temperature ratings, the lines will maintain adequate clearances and have elevated temperature effects adequately mitigated and managed consistent with the intent of the Normal Thermal Line Rating criteria. The elevated temperature ratings are continuous thermal ratings which, when utilized, shall be managed to ensure that the facility operates within its elevated temperature rating limits, and any adverse mechanical, electrical, or thermal impacts are adequately mitigated.

4.3.1.3 Industry Standards

Bare overhead transmission conductor ratings at BPA are established with the methodology described in the IEEE Standard for Calculating the Current-Temperature of Bare Overhead Conductors (IEEE Standard 738 –2006).

4.3.1.4 Input Criteria Assumptions

Summarized in the following sections is the BPA criteria used in the methodology described in the IEEE Standard for Calculating the Current-Temperature of Bare Overhead Conductors (IEEE Standard 738 –2006). The weather conditions are derived from the meteorological conditions found in BPA's service area and the CIGRE Technical Brochure 299 "Guide for Selection of Weather Parameters for Bare Overhead Conductor Ratings" published in August 2006.

4.3.1.4.1 Weather Conditions for rating overhead transmission conductors

- **Ambient Air Temperature:** BPA's current amperage rating criteria uses seasonally adjusted ambient air temperature of -10, 0, 5, 10, 20, and 30 degrees C.

  Note: BPA assumes a higher wind speed due to solar mixing at 40 degrees C and above.

- **Wind Speed:** BPA's amperage rating criteria uses a 2 foot per second wind (normal to conductor).

- **Solar Radiation**: BPA's amperage rating criteria uses full sun, clear atmosphere, day and night.

4.3.1.4.2 Maximum Normal Conductor Operating Temperatures

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Maximum normal conductor temperatures are established based on operating experience and IEEE Std 1283-2004 "Guide for Determining the Effects of High-Temperature Operation on Conductors, Connectors, and Accessories." Summarized in the table below are the maximum normal conductor operating temperatures used for the different transmission conductor types at BPA.

Table 1.— Maximum Normal Operating Temperatures*

Conductor Type	Maximum Normal Operating Temperature
ACSR and ACSR/TW	100 degree C
AAAC	100 degree C
AAC and AAC/TW	100 degree C
ACSS	150 degree C
Copper Hard Drawn	100 degree C

***Note:** The maximum continuous operating temperatures shown in Table 1 are upper limits to control conductor damage due to elevated temperature operation. Some line sections are limited by other considerations (i.e., clearances) and hence are not rated to operate at the maximum operating temperatures specified in Table 1.

4.3.1.4.3 Maximum Elevated Conductor Operating Temperatures

Maximum elevated conductor temperatures are established based on operating experience; IEEE Std 1283-2004 "Guide for Determining the Effects of High-Temperature Operation on Conductors, Connectors, and Accessories"; and EPRI research and development on the Mitigation Methods of High Temperature Conductor Operations. Summarized in the table below is the maximum elevated conductor operating temperatures used for the different transmission conductor types at BPA.

Table 2.— Maximum Elevated Operating Temperatures*

Conductor Type	Maximum Elevated Operating Temperature
High Steel Content ACSR and ACSR/TW	175 degree C
ACSS	200 degree C

***Note:** The maximum elevated operating temperatures shown in Table 2 are upper limits to control conductor damage due to elevated temperature operation. Some line sections are limited by other considerations (i.e., clearances) and hence are not rated to operate at the maximum operating temperatures specified in Table 2.

4.3.2 *Underground and Submarine Transmission Cable Equipment Ratings*

4.3.2.1 Normal and Emergency Rating Criteria

Normal Ratings for underground transmission cables are determined using the rating methodology below. BPA does not have ratings above normal for these cables. Therefore, no Emergency Ratings are provided as they would be equal to the Normal Ratings.

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4.3.2.2 Industry Standards

BPA Underground Transmission Facilities are designed per the following applicable industry standards:

- BPA does not have High Pressure Pipe Type cables.
- For low pressure self contained type cables and accessories, the industry standard used includes the Association of Edison Illuminating Companies specification CS4-93 (AEIC CS4-93 Specifications for Impregnated Paper Insulated Low and Medium Pressure Self Contained Liquid Filled Cable).
- For Solid Dielectric Crosslinked Polyethylene (XLPE) cables and accessories, the industry standard used is AEIC CS7-93 (Specifications for Crosslinked Polyethylene Insulated Shielded Power Cables Rated 69 through 138kV). And, IEC 60840 Power cables with Extruded Insulation is used for the accessories for rated voltages above 30 kV to 150 kV, Test Methods and Requirements.

4.3.2.3 Rating Algorithms

The AEIC cable standards listed above specify the allowable temperatures for various types and voltages of cable insulations which govern how much current may be transferred through the insulated conductor of the cable. BPA uses two common algorithms for calculating the predicted insulation temperature and thus the allowable operating ampacity.

The BPA preferred algorithm is that of the Neher-McGrath method outlined in "The Calculation of Temperature Rise and Load Capability of Cable Systems," in AIEE Transactions on Power Apparatus and Systems, vol. 76, October 1957.

An alternate and equally acceptable method is that outlined in the European IEC standard, "Calculation of the Continuous Current Ratings of Cables, (100% Load Factor), Publication 287, 2nd Edition, 1982.

4.3.2.3.1 Rating Methods

BPA rates cables using the above algorithms in the following ways:

- The cable manufacturer's cable calculations using the above algorithms and proprietary software.
- Neher-McGrath method utilizing the MathCad program.

4.3.2.3.2 Input Criteria Assumptions

The BPA inputs to the underground cable rating algorithms are as follows:

- Earth Ambient Temperature: Assumed to be 9 degrees Celsius during the winter months (the cable's peak loading period) and to be 25 degrees Celsius during the summer months per the EPRI Underground Transmission Systems Reference Book (1992 Edition, p. 209) unless can be proved otherwise.

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- Soil Thermal Resistivity: Based on backfill properties and Moisture Content. Soil thermal resistivity to be determined at each location an underground line is installed, in the form of a "Dry-Out Curve." Note: The land part of both submarine cables No. 4 and 5 utilizes thermal (controlled) backfills.
- Moisture Content: Moisture content in the Pacific Northwest will probably not be less than 5% during summer. However, a lower moisture content was assumed for the cable design.
- Load Factor of Underground Line: Obtained for each line, but the design assumes it to be 75%.
- Cable Depth: To be based on proposed route profile and local code restrictions. Typically, one meter has been used.
- Fault Current: Obtained from a system fault study for each proposed installation.
- Adjacent Heat Sources: (i.e., adjacent cable runs, adjacent heat pipes, distribution lines, or transmission lines) are taken into account as outlined in the EPRI Underground Transmission Systems Reference Book (1992 Edition).
- Cable Characteristics: The cable's characteristics (conductor size, material, stranding, bonding method, insulation thickness, etc.) are used to determine the cables thermal and electric losses.

4.3.3 *Transmission Line Element Ratings*

The transmission line element of a transmission line facility consists of the amalgamation of all of the included line sections. Each transmission line may have different conductor sizes, types, bundle configurations, and connector types resulting in different ampacity ratings for individual line sections that comprise the transmission line. A particular transmission line element is rated based on the most limiting rating of its associated sections.

4.3.4 *Transmission Line Facility Ratings*

Transmission Line Facility ratings are based on the most limiting rating among:

- Transmission Line Conductor elements
- Terminal Equipment elements (circuit breakers, disconnect switches, etc.), see Section 4.2.
- Series elements (line switches, transformers, series capacitors, etc.), see Section 4.2.

Examples:

Normal Line – The transmission line facility rating is set at the most limiting among the conductor element rating(s), the terminal circuit breakers, and the associated disconnect switches.

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Series Compensated Line – The transmission line facility rating is set at the most limiting among the conductor element rating(s), the terminal circuit breakers and their associated disconnect switches, and the series capacitor element.

Transformer Terminated Line – The transmission line facility rating is set at the most limiting among the conductor element rating(s), the terminal circuit breakers and their associated disconnect switches, and the transformer element.

4.4 Relay Settings

BPA's relay settings for all transmission lines at 200 kV and above, and some lines below 200 kV as determined per NERC Standard PRC-023, are set so that they will not limit the load carrying ability of the protected element. This is done by adhering to the NERC Standard for Transmission Relay Loadability, PRC-023, as detailed below.

4.4.1 *Relay Settings - Transmission Lines*

The relays are set such that they will not operate at or below 150% of the line's four-hour current rating for voltages down to 85% of nominal and current phase angles between 30 degrees leading and 30 degrees lagging. BPA does not define a four-hour current rating for its lines, so the continuous rating of the transmission line is used instead, as allowed by NERC Standard PRC-023. The continuous rating for the line at -10˚C is used.

4.4.2 *Relay Settings - Transformers*

Transformer relays are set according to NERC Standard PRC-023 so that they allow the transformer to be operated at an overload level of 150% of the transformer nameplate rating or 115% of the emergency transformer rating, whichever is greater.

4.5 Facility Ratings Methodology - Distribution Policy for External Review

The Bulk Electric System Facility Ratings Methodology (FRM), STD-D-000011, is published on the internal BPA Transmission Services Standards website. Upon request, the Communications & Grid Modeling Group (TPM) will provide STD-D-000011 to those Reliability Coordinators, Transmission Operators, Transmission Planners, and Planning Authorities that have responsibility for the area in which the associated Facilities are located, within 15 business days (21 calendar days) of receipt of an official request.

Additionally Facility Ratings are posted on WECC website in the base cases submitted to Western Electricity Coordinating Council (WECC).

4.6 Response to Comments Received by External Entities

When a Reliability Coordinator, Transmission Operator, Transmission Planner, or Planning Authority provides written comments on its technical review to the FRM (STD-D-000011), BPA will provide a written response to the comments with evidence within 45 calendar days of receipt of the comments. Changes made to the FRM will be included with the response.

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5. REFERENCES

AEIC CS4-93, Impregnated-Paper-Insulated-Low & Medium Pressure Self-Contained Liquid Filled Cable

AEIC CS7-93, Specifications for Crosslinked Polyethylene Insulated Shielded Power Cables Rated 69 through 138 kV

AIEE Transactions Part III - Power Apparatus and Systems, Vol. 76, October 1957

ANSI C93.3, American National Standard - Requirements for Power-line Carrier Line Traps

ANSI/IEEE C37.04, IEEE Standard Rating Structure

ANSI/IEEE C37.010, IEEE Application Guide for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis

ANSI/IEEE C37.010b, IEEE Standard for Emergency Load Current-Carrying Capability

ANSI/IEEE C37.010e, (Supplement to ANSI/IEEE C37.010), IEEE Application Guide for AC High - Voltage Circuit Breakers Rated on a Symmetrical Current Basis

ANSI/IEEE C37.011, IEEE Guide for the Application of Transient Recovery Voltage for AC High-Voltage Circuit Breakers

ANSI/ IEEE C37.06, IEEE Standard for Switchgear- AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis- Preferred Ratings and Related Required Capabilities.

ANSI/IEEE C37.06.1, Guide for High-Voltage Circuit Breakers Rated on Symmetrical Current Basis Designated "Definite Purpose for Fast Transient Recovery Voltage Rise Times"

ANSI/IEEE C37.09, IEEE Standard Test Procedure for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis.

ANSI/ IEEE C37.016, IEEE Standard for AC High Voltage Circuit Switchers rated 15.5 kV through 245 kV.

ANSI/IEEE C37.11, IEEE Standard Requirements for Electrical Control for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis

ANSI/IEEE Std 1030 – 1987 “IEEE Guide for Specification of High-Voltage Direct-Current Systems. Part I – Steady State Performance.

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Bonneville Power Administration (BPA), U.S. Dept. of Energy. STD-DS-000013, Bus and Bus Fittings Standard, Portland, Oregon.

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BPA, Pacific Northwest Icing Study, Report No. MRI 77 FR-1515, Contract No. 14-03-6046N, September 30, 1977 done by Meteorology Research, Inc.

CIGRE Technical Brochure 299 “Guide for Selection of Weather Parameters for Bare Overhead Conductor Ratings” published in August 2006

EPRI Underground Transmission Systems Reference Book, 1992 Edition.

FAC-008-3 – Facility Ratings, North American Electric Reliability Corporation (NERC).

Glossary of Terms Used in NERC Reliability Standard, North American Electric Reliability Corporation (NERC), April 5, 2013.

IEC 287, Calculation of the Continuous Current Rating of Cables, Second Edition, 1982.

IEC 60700-1 Thyristor Valves for High Voltage Direct Current (HVDC) Power Transmission – Part 1: Electrical Testing

IEC 60840 Power Cables With Extruded Insulation and Their Accessories for Rated Voltages Above 30 kV (*U*m = 36 kV) up to 150 kV (*U*m = 170 kV) - Test Methods and Requirements

IEC/TR 60919-1 Performance of High Voltage Direct Current (HVDC) Systems

IEC 61803 Determination of Power Losses in High Voltage Direct Current (HVDC) Converter Stations

IEC 62271-100-2008 High-voltage switchgear and controlgear - Part 100: Alternating current circuit-breakers (Annex N)

IEEE Std. C2 (Latest approved version per BPA Standard STD-DT-000005) – National Electrical Safety Code (NESC)

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IEEE C37.116, IEEE Guide for Protection Relaying Applications to Transmission Connected Series Capacitors.

IEEE C37.30, IEEE Standard Requirements for High-Voltage Switches.

IEEE C37.37, IEEE Standard Loading Guide for AC High-Voltage Switches (in excess of 1000 volts).

IEEE C37.37a, IEEE Standard Loading Guide for AC High-Voltage Air Switches Under Emergency Conditions

IEEE C37.99, IEEE Guide for the Protection of Shunt Capacitors Banks

IEEE C57.13 , IEEE Standard Requirements for Instrument Transformers, For Protection and Metering applications

IEEE C57.13.6, IEEE Standard for High-Accuracy Instrument Transformers, For Metering with High Accuracy and Extended Range Applications

IEEE C57.16, IEEE Standard Requirements, Terminology, and Test Code for Dry-Type Air-Core Series-Connected Reactors

IEEE C57.21, IEEE Standard Requirements, Terminology, and Test Code for Shunt Reactors Rated Over 500 kVA

IEEE C57.91, IEEE Guide for Loading Mineral-Oil-Immersed Transformers and Step-Voltage Regulators

IEEE Std. 18, IEEE Standard for Shunt Power Capacitors

IEEE Std. 605, IEEE Guide for the Design of Substation Rigid-Bus Structures - methodology for determining bus ampacity

IEEE Std. 738 - 2006, IEEE Standard for Calculating the Current-Temperature of Bare Overhead Conductors.

IEEE Std. 824 - 2004, IEEE Standard for Series Capacitor Banks in Power Systems.

IEEE Std. 857, IEEE Recommended Practice for Test Procedures for High-Voltage Direct-Current Thyristor Valves.

IEEE Std. 1031 - 2000, IEEE Guide for the Functional Specification of Transmission Static VAR Compensators

IEEE Std. 1036, IEEE Guide for the Application of Shunt Power Capacitors

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IEEE Std. 1283-2004, IEEE Guide for Determining the Effects of High-Temperature Operation on Conductors, Connectors, and Accessories.

IEEE Std. 1534 – 2002, IEEE Recommended Practice for Specifying Thyristor-Controlled Series Capacitors (TCSC)

NEMA SG 4, High-Voltage Circuit Breakers

NERC Docket No. RD11-10-000

NERC Standard PRC-023-1, Transmission Relay Loadability

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APPENDIX

A. Facility Rating Data in BPA Base Cases- BPA Base Case Facility Ratings

The following ratings are in the branch data files:

- Rate_N Nominal Rating
- Rate_WT Winter Peak Thermal Rating
- Rate_WE Winter Peak Emergency Rating
- Rate_WB Winter Peak Bottleneck Rating
- Rate_SpT Spring Thermal Rating
- Rate_SpE Spring Emergency Rating
- Rate_SpB Spring Bottleneck Rating
- Rate_SuT Summer Thermal Rating
- Rate_SuE Summer Emergency Rating
- Rate_SuB Summer Bottleneck Rating

The branch data ratings are in MVA for lines and for transformers. The thermal line ratings for BPA lines are the allowable current ratings consistent with the following ambient air temperatures (deg C):

Table 3.—Ambient Air Temperatures for Line Ratings

Load Period	Lines West of Cascades	Lines East of Cascades
Normal Winter (1-in-2 probability)	-5 degrees C	-15 degrees C
Spring	20 degrees C	20 degrees C
Summer	30 degrees C	30 degrees C

For the line compensation sections, the I-½ hour amps are used for thermal and emergency ratings.

The MVA ratings for BPA transformers are obtained from the BPA-Owned Transformer Loading Guide. The loading guide for each transformer has the appropriate rows for ambient temperature highlighted for Abnormal Winter, Intermediate Winter, Normal Winter, Spring, and Summer.

- The thermal ratings are under the Loading Capability columns. The ratings under the Forced Cooled column are used if they are available. Otherwise, the numbers under Self Cooled column are used.
- The emergency ratings are listed under Emergency MVA Capabilities. Winter and summer values are provided for 0.9, 0.8, 0.7, and 0.6 weekly load factors. If a transformer location is not documented, a 0.7 load factor is used for winter and 0.8 for summer. The summer emergency rating for a BPA transformer is also used for the spring emergency rating.

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- The transformer rating, called the bottleneck rating, is the rating associated with bushing capability. The Transformer Loading Guide has columns under Bushing Capability for High Side and Low Side. The branch data emergency rating is the lower (more limiting) rating of the two ratings. The Transformer Loading Guide uses the seasonal rating.

Other utilities provide their line and transformer ratings. The branch data program allows the selection of a year and month for producing GE epc branch records for a case. The export form also has other choices:

- The program has a place to select the line and transformer Access tables.
- The appropriate ratings for the season are the first choice. The program defaults to other ratings when the first choice is unavailable for any column.
- If a branch does not have any non-nominal ratings, the nominal rating is used for all the ratings in the GE epc branch records.
- The new branch data program techniques can now result in branches without nominal ratings. When a GE epc file is used to produce branch data records, the branches do not have nominal ratings. However, they should have other ratings that would be used in preference to the nominal ratings.
- If no Spring ratings exist in branch data, the program defaults to summer (if summer branch data ratings exist) or nominal (if summer branch data ratings do not exist). Several utilities provide winter and summer ratings for the branch data so the summer branch data ratings are used for the spring and fall case ratings in the epc file for those branches.
- If at least one spring rating exists in branch data but other spring ratings are zero or blank, the spring ratings that exist will be used for the spring case ratings. For example, if a branch has a spring thermal rating but no other spring ratings and the branch has thermal and bottleneck summer ratings, the program will use the spring thermal rating in branch data for both spring case ratings in the epc file.
- The branch data files do not have fall ratings. The ratings used for spring case ratings will be used for fall case ratings.

B. Facility Rating Data in BPA Base Cases- Branch Ratings in the 8-Rating GE Cases

The 8-rating GE cases have branch ratings for all seasons and follow the same convention as the WECC cases. The 8-rating GE cases only have 2 ratings per season. The ratings in the 8-rating GE cases are:

- 1st Line Rating = Normal Summer = lower of thermal or bottleneck
- 2nd Line Rating = Emergency Summer = emergency if it exists (otherwise same as the 1st rating)
- 3rd Line Rating = Normal Winter = lower of thermal or bottleneck

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- 4th Line Rating = Emergency Winter = emergency if it exists (otherwise same as the 3rd rating)
- 5th Line Rating = Normal Fall = lower of thermal or bottleneck - used spring ratings
- 6th Line Rating = Emergency Fall = emergency if it exists (otherwise same as the 5th rating)
- 7th Line Rating = Normal Spring = lower of thermal or bottleneck
- 8th Line Rating = Emergency Spring = emergency if it exists (otherwise same as the 7th rating)
- 1st Transformer Rating = Normal Summer = lower of thermal or bottleneck
- 2nd Transformer Rating = Emergency Summer = lower of bottleneck or emergency
- 3rd Transformer Rating = Normal Winter = lower of thermal or bottleneck
- 4th Transformer Rating = Emergency Winter = lower of bottleneck or emergency
- 5th Transformer Rating = Normal Fall = lower of thermal or bottleneck - used spring ratings
- 6th Transformer Rating = Emergency Fall = lower of bottleneck or emergency – used spring ratings
- 7th Transformer Rating = Normal Spring = lower of thermal or bottleneck
- 8th Transformer Rating = Emergency Spring = lower of bottleneck or emergency

Most lines do not have emergency ratings in the branch data program. Therefore, most line ratings for Northwest lines will have the same rating for the normal and emergency rating.

If transformers do not have emergency or bottleneck ratings in the branch data program files, the emergency transformer rating on the GE transformer record for each season will match the normal transformer rating for that season.

C. Facility Rating Data in BPA Base Cases- Branch Ratings in PowerWorld Cases

The branch ratings in the PowerWorld cases match the ratings for the 8-rating GE cases. The ratings are restricted to the season of the particular case.

- Line Limit A = Normal Summer = lower of thermal or bottleneck
- Line Limit B = Emergency Summer = emergency if it exists (otherwise same as Line Limit A)
- Line Limit C = Normal Winter = lower of thermal or bottleneck
- Line Limit D = Emergency Winter = emergency if it exists (otherwise same as Line Limit C)
- Line Limit E = Normal Fall = lower of thermal or bottleneck - used spring ratings

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- Line Limit F = Emergency Fall = emergency if it exists (otherwise same as Line Limit E)
- Line Limit G = Normal Spring = lower of thermal or bottleneck
- Line Limit H = Emergency Spring = emergency if it exists (otherwise same as Line Limit G)
- Transformer Limit A = Normal Summer = lower of thermal or bottleneck
- Transformer Limit B = Emergency Summer = lower of bottleneck or emergency
- Transformer Limit C = Normal Winter = lower of thermal or bottleneck
- Transformer Limit D = Emergency Winter = lower of bottleneck or emergency
- Transformer Limit E = Normal Fall = lower of thermal or bottleneck - used spring ratings
- Transformer Limit F = Emergency Fall = lower of bottleneck or emergency – used spring ratings
- Transformer Limit G = Normal Spring = lower of thermal or bottleneck
- Transformer Limit H = Emergency Spring = lower of bottleneck or emergency

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