BONNEVILLE POWER ADMINISTRATION

Bulk Electric System Facilities Rating Methodology
STD-D-000011

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1. INTENT

This standard provides the current BPA rating methodology for the following Bulk Electric System 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-008-1, approved by NERC Board of Trustees with an effective date of August 7, 2006.

2. DEFINITIONS

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.

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.

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 substation~~s~~, line tap~~s~~ (generation insertion or load serving), or step up/down power transformer(s) in the line between breakers. The physical line between substations or line taps are termed “transmission line sections.”

3. BACKGROUND

BPA bases its rating methodology on industry standards and original equipment manufacturer (OEM) ratings as discussed below. Both standards and initial OEM ratings may have changed over the years and BPA modifies its rating methodology from time to time to keep pace with accepted industry practice. This standard describes BPA

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current methodology and makes no assumptions as to the design criteria of legacy equipment and facilities.

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 elements. For example, a transmission line may include conductors, line traps, switches, breakers and protective relays. All this equipment or elements operate together with the limiting facility rating being derived from the individual equipment ratings. Thus **the facility rating is limited by the most limiting equipment rating.**

Since the limits for any facility must first be defined at the individual equipment/element level this document organizes the elements into two major categories as listed below. The equipment or element descriptions are further defined under the section headings for these categories.

3.1 Revision History

- Revision 00, 4/28/11: Initial approval of standard. This standard supersedes document, BPA Bulk Electric System Facilities Rating Methodology, Revision dated April 07, 2008.

4. POLICY AND APPLICATION

4.1 Transmission Lines

Transmission line facilities are comprised of three main sets of equipment: transmission substation terminal equipment, with-in line substation high-side equipment and transmission line conductors. Line conductors are almost exclusively overhead conductors with a few underground cables entering substations and a few sea cables serving islands in Puget Sound. The transmission terminal equipment includes breakers, switches, line traps, buswork, current transformers and protective relays. Switches and buswork also comprise substation high-side equipment. Since all associated transmission line equipment is also used in other facilities besides transmission lines, the rating methodology for this equipment is shown under a separate section, “Substation Elements”. Each transmission line section may have multiple conductor sizes, types, and ampacity ratings. A particular transmission line or line section is rated based on the most limiting rating of its associated equipment. In some cases the limiting element for a line may change with various switching arrangements. Since these situations require local switching at the substation, such situations are handled with Station Instructions at the substation. Changes in the limiting element for a line will be reported to the appropriate BPA control center by the BPA substation Operator. For the purpose of this document an autotransformer in series with a transmission line is treated as a separate facility with its own ratings.

4.1.1 *Overhead Transmission Lines*

4.1.1.1 Normal Rating Criteria

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Normal Ratings for overhead transmission conductors are determined using the rating methodology described below. The ampacity ratings of bare overhead conductors at BPA are:

- Based on the steady state load current carrying capacity of the conductor and its connectors.
- A continuous thermal rating based on a maximum rated conductor temperature which ensures safe and reliable facility operation, hence considers clearances and elevated temperature effects. This rating serves as the "normal" or "full-time" continuous rating for the line section.

4.1.1.2 Emergency Rating Criteria

Emergency ratings for overhead transmission conductors at BPA are presently extremely rare. In all cases where emergency ratings are employed, the same criteria as discussed under Normal Rating Criteria is utilized, except the conductors maximum temperature is in excess of the values specified under "Maximum continuous conductor operating temperatures". Under the Emergency Rating, the line shall maintain adequate clearances and have elevated temperature effects either adequately mitigated or managed consistent with the intent of the Normal Rating Criteria. The Emergency Rating is a continuous thermal rating of limited duration, which when utilized, shall be monitored and managed to ensure the facility operates within its Emergency Rating limits and any adverse mechanical or thermal impacts are adequately mitigated.

4.1.1.3 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).

4.1.1.4 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.

4.1.1.4.1 Weather Conditions for rating overhead transmission conductors:

- **Ambient Air Temperature:** BPA's current ampacity rating criteria uses seasonally adjusted ambient air temperature of -10 degree C, 0 degree C, 5 degree C, 10 degree C, 20 degree C, and 30 degree C. Note: The primary database used to document element ratings supports an ambient temperature of 40 degree C. Since 40 degree C is not used in conductor thermal ratings, the database ampacity ratings for 30 degree C and 40 degree C are equal for database compatibility purposes.

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- **Wind Speed:** BPA's current ampacity rating criteria uses a 2 foot per second wind (normal to conductor).
- **Solar Radiation**: BPA's current ampacity rating criteria uses full sun, clear atmosphere, day and night.

4.1.1.4.2 Maximum continuous conductor operating temperatures:

Maximum continuous 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 is the maximum continuous conductor operating temperatures used for the different transmission conductor types at BPA.

Table 1.—Maximum Continuous Operating Temperatures*

Conductor Type	Maximum Continuous 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. Many line sections are limited by other considerations (i.e., clearances) and hence do not necessarily carry the maximum operating temperatures specified in Table 1.

4.1.2 *Underground and Submarine Transmission Cable*

4.1.2.1 Normal and Emergency Rating Criteria

Normal Ratings for underground transmission cables are determined using the below rating methodology. 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.

4.1.2.2 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).

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- 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, IEC60840 Power cables with Extruded Insulation for their accessories for rated voltages above 30 kV to 150 kV Test Methods and Requirements.

4.1.2.3 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.

4.1.2.3.1 Acceptable 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.

4.1.2.3.2 Input Criteria Assumptions

The BPA inputs to the underground 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.
- **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 assumed it to be 75%.

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- **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.

4.2 Substation Elements

Substation elements include equipment specifically associated with a transmission line facility, generally referred to as "terminal equipment" within a substation environment. Substation elements also include all other equipment that generally serve multiple lines or facilities as in the case of bus tie and sectionalizing breakers; most power transformers, capacitors, reactors, and associated relays.

Substation elements are generally rated by a combination of manufacturer nameplate rating, industry standards, and in some cases by test for uniquely designed equipment.

4.2.1 *Transformers*

Transformer facilities include power transformers, current transformers, and associated connected equipment. Associated equipment connected to the transformer such as breakers, buswork, switches and protective relays associated with transformer facilities are shown under section entitled "Substation Elements." For new installations, this other equipment shall be designed not to be limiting elements for the operation of the transformer. Therefore the transformer ratings become the limiting ratings of the facility. For transformer replacements, this other equipment may become limiting elements for the transformer facility.

4.2.1.1 <u>Power Transformers</u>

Transmission system transformers on the bulk electric system are rated on an individual basis. These ratings are maintained on a list that includes the substation name, the BPA equipment company asset number or location within the substation, the transformer 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 standard.
- "PT-Load" computer program developed by Electric Power Research Institute (EPRI). This program utilizes the algorithms in the above IEEE C57.91 loading

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guide. BPA uses this program to evaluate special conditions (mostly short-term conditions) that fall outside of the standard loading guides discussed under item 1 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 not 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 Current Transformers

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

- IEEE Standard Requirements for Instrument Transformers, C57.13.

BPA rates transmission instrument transformers according to the manufacturer's specifications with nominal ratings shown on the nameplate. BPA does not have ratings above normal for transmission instrument transformers therefore the emergency ratings would be identical to normal ratings. BPA maintains a stock of critical instrument transformers for emergencies.

4.2.2 *Shunt Reactors*

Shunt reactors in support of 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

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 are rated per 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).

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4.2.3 *Series Reactors*

Transmission series connected reactors are specified and rated according to:

- ANSI/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.

For new installations, other associated power system equipment connected to the series reactor such as breakers, switches, buswork and relay settings are designed not to be limiting elements for the operation of the reactor. Therefore the reactor ratings become the limiting ratings of the facility. For series reactor replacements, this other equipment may become limiting elements for the Series Reactor Facility. The rating methodology for these other devices is provided under section "Terminal Equipment".

4.2.4 *Switchgear*

Switchgear includes all those devices use to interrupt fault current, switch reactive devices, or provide electrical isolation and may be operated external control circuits or manually as in the case of disconnects.

4.2.4.1 Circuit Breakers

AC high-voltage circuit breakesr are specified by operating voltage, continuous current, interrupting current, and operating time in accordance with ANSI/IEEE Standards C37 series, "Symmetrical Current Basis." These ratings are indicated on the individual circuit breaker manufacturer nameplate. The following standards are referenced in the breaker specifications:

- ANSI C37.04, IEEE Standard Rating Structure
- ANSI C37.06, Standard for Switchgear- AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis- Preferred Ratings and Related Required Capabilities.
- ANSI C37.09, IEEE Standard Test Procedure for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis.
- IEEE C37.010b, Standard for Emergency Load Current-Carrying Capability
- IEEE C37.010e, (Supplement to IEEE C37.010).

BPA rates transmission circuit breakers according to the manufacturer's specifications. The Normal Rating for BPA transmission circuit breakers are rated as shown on the manufacturer's nameplate. Nameplate interrupting ratings are adjusted for reclosing of oil circuit breakers per ANSI C37.04, IEEE Standard Rating Structure. Ratings above normal for transmission circuit breakers are determined according to the above referenced standards.

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4.2.4.2 Disconnect Switches

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, Standard Requirements for High-Voltage Switches.
- IEEE C37.37, Standard Loading Guide for AC High-Voltage Switches (in excess of 1000 volts).
- IEEE C37.37a, Standard Loading Guide for AC High-Voltage Air Switches Under Emergency Conditions.

4.2.4.3 Circuit Switchers

AC high-voltage Circuit Switchers (CS) are specified by operating voltage, continuous current, reactive switching current, interrupting current, and operating time in accordance with ANSI/IEEE Standards C37 series, "Symmetrical Current Basis." These ratings are indicated on the individual Circuit Switcher manufacturer nameplate. The following standards are referenced in the CS specifications:

- ANSI C37.06, C37.016

BPA rates transmission CS's according to the manufacturer's specifications. The Normal Rating for BPA transmission CS's are rated as shown on the manufacturer's nameplate. Ratings above normal for transmission circuit breakers are determined according to the above referenced standards.

4.2.5 *Shunt Capacitors*

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

- IEEE 18, IEEE Standard for Shunt Power Capacitors
- IEEE 1036, IEEE Guide for the Application of Shunt Power Capacitors
- IEEE C37.99, IEEE Guide for the Protection of Shunt Power Capacitors

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.

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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 ratings become the limiting ratings of the facility. The rating methodology for these other devices is provided under section, “Terminal Equipment”.

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.

4.2.6 *Series Capacitors*

Transmission series connected capacitors are specified and rated according to:

- IEEE 824 - 2004, IEEE Standard Requirements for Series Capacitors in Power Systems.
- ANSI/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.

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 facility. Where the banks are upgraded the short time rating of other devices may be limiting. The rating methodology for these other devices is provided under section “Terminal Equipment”.

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.

4.2.6.1 <u>Thyristor Controlled Series Capacitor (Slatt)</u>

Transmission TCSCs are specified and rated according to:

- IEEE 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 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

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between TCSC reactance, line current and various protective thresholds. When bypassed the bank is 1.2 ohm inductive.

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 ratings become the limiting ratings of the facility. The rating methodology for these other devices is provided under section “Terminal Equipment”.

4.2.7 *Static Var Compensators*

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

- IEEE 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 are rated 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.

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 Facility. The rating methodology for these other devices is provided under section, “Terminal Equipment”.

4.2.8 *DC Terminal (Pacific HVDC Intertie)*

The rating of the Pacific HVDC Intertie has been dictated by historical technologic capability of HVDC equipment and the continuing need for increased power transfer between the Pacific Northwest and Pacific Southwest over the life of the Intertie.

4.2.8.1 Industry Standards:

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

4.2.8.2 System Description

The original Intertie planning in the mid 1960’s called for two DC Interties. DC Poles 1 and 2 were to go on a bipole line from The Dalles, Oregon to Hoover Dam (Lake Mead). DC Poles 3 and 4 were to go on a bipole line from The Dalles, Oregon to Sylmar, California. At the time, HVDC technology for bipole connections had capability limits of 1800Adc at 400kvdc per pole. This set each system ratings at 1440MW per DC bipole system. A connecting link between Sylmar and Mead was to be added to complete the

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loop. (Reference "The BPA EHV D-C Program May 1965 Division of Engineering) In the event of an outage on either DC line from Celilo, the remaining in-service line was to carry double the normal rated current to maintain full Northwest–Southwest power transfer. This dictated a line conductor rating of 3600Adc (1800Adc x 2). The conductors needed to endure the resulting thermal stress up to a total accumulated time of 1000 hours during the life of the line, with no appreciable loss of mechanical strength. The DC link project portion to Hoover Dam (Poles 1 and 2) was canceled before construction but because of the full NW – SW power transfer design criteria, the DC line to Sylmar which was built carries the 2x rating (3600Adc).

(Reference – 800kv dc transmission Report). **Note:** a small line section was not built to the design value.

Additional capacity was added to the system by voltage upgrading of the lines and terminals to +-500kvdc rating in 1985. From this power envelope of 500kVdc and 3600Adc line capability, we move to the actual rating of the present system and components described in the next section.

4.2.8.3 Normal 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. At the last DC system capacity increase when parallel converters per pole were added in 1989, system planners determined that the worst case 1988 light spring AC power flow studies remained stable up to 3100MW on the DC. This set the present DC converter equipment power limit and AC connection equipment limits for steady state transfer on the DC system.

(References – BPA Terminal Expansion Plan of Service, EPRI Report – "Methodology for Integration of HVDC Links in Large AC Systems – Phase I and II"

BPA Memoranda:

- "HVDC Terminal Expansion Plan-of-Service" May 1984.
- "Performance Goals for the HVDC Expansion Project" 5/17/1984 by Edward J. Yasuda.
- "HVDC Terminal Expansion—Selection of Capacity.
- "Addition of Parallel Converters on Existing DC Intertie" 10/7/1983 by Dr. John J. Vithayathil.

4.2.8.4 Emergency Rating Criteria

BPA specified a ten minute overload capability of 150% in the Converter 1 and 2 equipment and Converter 3 and 4 equipment have a 10% overload capability for one hour giving Celilo Converter Station short-term equipment rating of 3850MW. At present, the overload capability is only used for temporary make up of power lost due to

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tripping of other converters. It is not to exceed 3100MW. Sylmar Converter Station equipment rating is 3100MW. The Sylmar rating can be increased with increased cooling capacity.

Reference - Sylmar Rebuild Design Studies

4.2.9 *Line Traps*

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 the 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. Line traps are commercially available for one or two frequencies and for transmission line currents of 400, 800, 1200 and 1600 Amps and higher. Reference Document:

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

The Normal Rating for BPA line traps are rated 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.

4.2.10 *Bus Conductors, Fittings and Attachments*

The electrical conductivity of various materials that BPA uses in buswork is listed in Table 2 below. Aluminum 6101-T6 is the preferred conductor for bus, while 6061-T6 is mainly used in the fabrication of bus fittings.

Table 2.—Bus conductor alloys and conductivity.

Material	Alloy and/or Temper	% Conductivity (Based on "pure" Copper)
Aluminum	6061-T6	40%
	6063-T6	47-54% (typically 53%)
	6101-T6	57%
Copper	Hard-Drawn	98%

The ampacity rating of buswork is based on its ability to dissipate heat and the allowable temperature rise above the ambient temperature. BPA uses the industry standard of a 30º rise over a 40ºC ambient temperature. When necessary, this rating can be exceeded, but only after careful analysis of the system parameters and the ramifications of allowing higher bus temperatures. BPA uses IEEE 605 methodology for

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determining bus ampacity. For new installations, BPA's standard should always be followed.

The majority of bus conductors installed at BPA are simply supported between two pedestals. At BPA, nearly all outdoor bus conductors are tubular 6101-T6 aluminum. This material is always pre-stressed when span lengths are sufficient to produce any noticeable sag in a given span with no added ice or wind loading. BPA uses the methodology of IEEE 605 to determine span length.

BPA installs an expansion joint or other method of allowing linear bus movement every 90 feet (variation allowed for different layout configurations). Thermal expansion/contraction calculations are be based on a temperature of +/-70ºC from the installed temperature.

Shorter runs may need expansion measures if forces will cause malfunction of, or damage to connected equipment. This will be depending of the rigidity of the supporting/connecting equipment. Measures to mitigate seismic effects on major equipment will alleviate most problems with thermal expansion.

The best solution at present to prevent bus vibration is the use of a "Stockbridge" type of damper as manufactured by ALCOA. These dampers come in various styles, both internal and externally mounted. They are also available in various voltage classes. The installation point is found by determining the bus span length between supports, dividing by three, and adding two feet.

The maximum-expected wind is obtained from "Distribution of Extreme Winds in BPA Service Area," BPA, 1980. The 100 year mean recurrent level isotach is used. The value obtained is multiplied by the nearest gust factor.

The maximum expected ice is obtained from the Pacific Northwest Icing Study, Report No. MRI 77 FR-1515, Contract No. 14-03-6046N, September 30, 1977 done by Meteorology Research, Inc., for BPA. The 50 year ice charts are used.

Bus fittings, whether for current carrying or support functions, are typically fabricated from wrought aluminum. The exceptions are for copper bus and a limited number of aluminum fittings which are cast material. The reason that BPA has not, and will not universally use cast fittings as most of the electrical industry, is BPA's need for higher strengths for longer bus spans and the method of fitting/pre-stressing bus spans as previously mentioned.

All buswork at BPA is welded where possible. Exceptions to this rule are copper bus (which may be MIG welded or bolted). All welding on BPA electrical bus is to be done by welders who have passed the BPA Certified welding test. The minimum requirement found in the AWS is deemed not adequate for the quality control needed. For connections to equipment or to differing bus materials (for example -copper to aluminum bus), the preferred standard is stainless steel bolts with Belleville washers to compensate for different rates of thermal expansion. The second best and allowable choice is aluminum bolts of compatible alloy with hardened washers and semi-Belleville washers to allow proper torque as required with aluminum bolts. The third and least preferred method is the old BPA method of using Everdur bronze bolts for connections.

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All bolted connections shall agree with and comply with NEMA CC1 Standard for dimensions and ampacity.

4.2.11 *Relay Settings*

BPA's relay settings for all transmission lines at 200kV and above, and lines below 200kV specifically designated by WECC, are set so that they will not limit the load carrying ability of the transmission line. This is done by adhering to the NERC guidelines for relay loadability, specifically that the relays shall not operate at or below 150% of the lines four-hour current rating for voltages down to 85% of nominal and a current phase angle of up to 30 degrees lagging. BPA does not define a four-hour current rating for its lines, so the continuous rating of the transmission line (Bottleneck Report) is used instead, as allowed by the NERC guidelines. The continuous rating for the line at -10˚C is used.

Transformer relays are set according to NERC guidelines 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.

4.3 FRM Distribution Policy for External Review

The FRM is posted on the internal Transmission Services Standards website. Upon request, the Grid Modeling Office (TPM) will provide the FRM 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 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).

4.3.1 *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, BPA (Transmission Planner) 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.

5. REFERENCES

Glossary of Terms Used in NERC Reliability Standard, North American Electric Reliability Corporation (NERC), April 20, 2010.

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