BC Hydro	Transmission Maintenance Standard		
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Bulk Electric System	**Revision:**	8	
Facility Rating Methodology	**Date:** 25 November 2020		**Page 1 of 15**

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Lines and Taps Facilities		**Stations Facilities**	
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This document is due for review in 2021.

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1 INTRODUCTION

This document outlines the methodologies used for rating Bulk Electric System Facilities in the BC Hydro system. The equipment included in this document is that which have a potential limiting influence on the rating of a facility.

A BC Hydro facility will contain one or more elements, which are the different types of equipment (e.g. breakers, cables, transformers) found on the electric system. Any piece of equipment will have an individual rating; the facility's rating will equal the most limiting element's rating that comprises that facility. Facilities are divided into three categories: Lines, Taps, and Stations.

Lines are comprised of all linear equipment of a transmission line up to (and including) the breaker at the station. If the transmission line terminates at a bus, then the Line also includes the bus and equipment up to (and including) the breakers on either side of the termination. Non-series elements that do not affect the rating of the Line to which they are connected are not considered part of the Line.

Taps are transmission lines that branch from a Line to a Substation, generator, or load. Taps are limited to plant within BC Hydro's operating authority. Taps do not affect the rating of the Line to which they are connected.

Stations are made up of multiple facilities. Each facility connects two nodes in the topology of the station. They contain various equipment, such as transformers, circuit breakers, disconnect switches, instrument transformers, shunt reactors, shunt capacitors, series capacitors, wave traps and others. The rating of all the equipment, including interconnection busses and jumpers mentioned above are recorded in the associated signed and sealed engineering drawings. Interconnection buses and jumpers' ratings are determined by BC Hydro Engineering Standards and practices. The signed and sealed engineering single line diagram of each substation serves as the collection of all BES element's ratings. The operator must operate the system not exceeding the most limiting element's rating that comprises the facility.

Sections 2 through 14 describe how the ratings for each element are developed, while Appendix A shows examples of how elements form facilities in various configurations

2 TRANSMISSION LINES

Transmission lines are comprised of all the overhead and underground components that interconnect the generating stations, substations, and transmission voltage customers. Line conductors are mostly overhead conductors with some underground and underwater cables (including the associated cable fluid pumping apparatus). Other terminal equipment is described in separate sections. Transmission line ratings are based upon the section of the line with the lowest ampacity. Where a circuit has taps, the distribution of the loading on the segments of the circuit, and the locations of the telemetry must be considered. If taps exist for a circuit, and segment information is not provided, then the circuit limitation is based upon the minimum ampacity of all the segments and the segment and tap loading does not have to be considered. The means of determining a segment rating, based upon its line type, are listed in the following sections.

2.1 Overhead Transmission Line

2.1.1 Normal Rating Criteria

Normal ratings for bare overhead conductors are based on:

a The steady state load current carrying capacity of the conductor and its connectors.

b 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 continuous rating for the line section.

2.1.2 Emergency Rating Criteria

The same criteria as discussed under Normal Rating Criteria are utilized for emergency ratings, except that the conductor maximum temperature is in excess of the normal continuous operating temperature. 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.

2.1.3 Standards

Overhead transmission line ratings at BC Hydro are established with the methodology described in the following standards:

CSA C22.3 No.1-01	Standard for Overhead Systems
IEEE 738	Standard for Calculating the Current-Temperature of Bare Overhead Conductors

BC Hydro Standard ES-41.

2.1.4 Design Parameters

Summarized below are the design parameters used by BC Hydro in the IEEE Standard for Calculating the Current-Temperature of Bare Overhead Conductors (IEEE Standard 738). The weather conditions are derived from the meteorological conditions found in BC

Hydro's service area and the CIGRE Technical Brochure 299 "Guide for Selection of Weather Parameters for Bare Overhead Conductor Ratings".

a Voltage Rating
This is a design parameter based upon the operating voltage and future system requirements. Voltage rating affects clearance requirements.

b Ambient Air Temperature
BC Hydro's current ampacity rating criteria uses an average ambient air temperature of 0, 10, and 30°C.

c Wind Speed
BC Hydro's current ampacity rating criteria based on the geographical area and metrological data. If not available, a nominal wind speed of 0.6 m/s is used.

d Load Conditions
Snow or Ice load: based on the geographical area and the metrological data.

e Maximum continuous conductor operating temperatures
These are established based on operating experience and IEEE 1283, Guide for Determining the Effects of High-Temperature Operation on Conductors, Connectors, and Accessories. The maximum continuous conductor operating temperatures used for the different transmission conductor types at BC Hydro is 90°C.

Many line sections are limited by other considerations (i.e., clearances) and hence do not necessarily carry the maximum operating temperatures. The maximum continuous conductor operating temperature is the upper limit to control conductor damage due to elevated temperature operation.

2.2 Underground Transmission Cable

2.2.1 Rating Algorithms

The steady-state and transient ratings are normally calculated using CYME software. On rare occasion, BC Hydro may also use algorithms based on the method described by Neher-McGrath (1957).

When dealing with thermal bottlenecks such as steam crossings or other distribution circuit crossings, finite element software packages such as MATHCAD, ALGOR, COMSOL, or EPRI's ACE are used to compute their impact on ratings.

2.2.2 Normal and Emergency Rating Criteria

Normal and emergency ratings for underground transmission cables are based upon the maximum allowable temperatures of the cable insulation at the conductor. The conductor temperature limit for kraft paper insulation and polypropylene laminated insulation used in HPFF and SCFF cables have been established at 85°C for normal operation, 105°C for 100 hour emergencies, and 100°C for 300 hour emergencies. The corresponding temperatures for XLPE insulated cables are 90°C for normal operation and 105°C for 216 hours in any single emergency event. There are no specific requirements for 300 hour emergency ratings on XLPE cables.

The governing temperature limits for SCFF cables and accessories are described in the Association of Edison Illuminating Companies specification AEIC CG1 (Guide for Establishing the Maximum Operating Temperatures of Impregnated Paper and Laminated Paper Propylene Insulated Cable). Similarly, the governing temperatures limits for XLPE cables and accessories are described in the AEIC CS9 (Specifications for Extruded Insulation Power Cables and Their Accessories Rated 46 kV through 345 kV).

2.2.3 Standards

Transmission cable ratings at BC Hydro are established with software whose computational engines are based on the following standards:

IEC 60287 Electric Cable – Calculation of the Current Rating

IEC 60853 Calculation of the Cyclic and Emergency Current Rating of Cables

In addition, design parameters used in establishing ratings can be found in:

BC Hydro Standard ES-42

2.2.4 Design Parameters

The design parameters used in establishing cable ratings for a given cable type and cable configurations are as follows:

a Voltage Rating
This is a design parameter based upon the operating voltage and future system requirements.

b Earth Ambient Temperature
In the Greater Vancouver and Greater Victoria areas, the maximum summer and winter ground ambient temperatures at cable burial depth of 1.5 m are assumed to be 22°C and 13°C, respectively. These maxima are considerably above the measured

nominal values in order to provide an allowance for the effect of local temperature anomalies.

c Soil Thermal Resistivity
These are measured and adjusted to allow for the driest soil conditions anticipated for each proposed circuit.

d Load Factor of Proposed Underground Line
These are obtained separately for each proposed circuit. If this is unknown the load factor is assumed to be 0.9.

e Cable Depth
This is based on the proposed route profile. Generally, the cables are placed in a 2X2 concrete encased duct bank configuration and the centerline of this duct bank configuration is assumed to be 1. 5 m below grade. If the cable is a direct-buried installation and the depth of burial is unknown the centre-line of cable burial depth is assumed to be 1.5 m.

f Fault Current
The fault current magnitude and the short-circuit durations are provided by the system fault study for each proposed installation.

g Cable configuration and bonding arrangements
The bonding arrangements and cable spacing can influence cable ratings and are accounted for in the ampacity calculations

h Adjacent Heat Sources
The presence of adjacent heat sources such as distribution cable circuits, steam pipes or transformer vaults are identified wherever possible to help assess their impact on cable ratings. Where the heat sources are not adjacent but cross the planned circuits, the classical calculation methods are inadequate. Finite element techniques are then applied to develop the steady-state ratings for such configurations.

i Cable Characteristics
The cable's construction (conductor size, material, stranding, bonding method, insulation thickness, etc.), dissipation factor of the main insulation system, thermal resistivity of the various materials used in the cable manufacture, and the corresponding heat capacities are used to determine the cables Joule and dielectric losses. It is assumed that the dielectric losses are a function of voltage alone and is temperature invariant.

2.3 Underwater Transmission Cable

The facility ratings methodology for underwater transmission cables is similar to that discussed above. The key differences are:

a The ambient summer and winter water temperatures are depth dependent. Generally, across the sea channels where these underwater cables are located, the water temperatures for summer and winter are assumed to be 8°C; steady-state and transient ratings are performed accordingly. It is assumed that the cables lay on top of the sea-bottom.

b The cables in the ocean are spaced either 200 m apart or two times the water depth (whichever is greater)

The conductor sizes are generally governed by the land section of the cable as the ambient soil temperatures are higher than the water temperatures.

The rating methodology for computing the ratings for DC underwater cables is similar to those adopted for AC underwater cables except that in the case of dc voltage application the dielectric loss, sheath and armor losses are ignored.

3 TRANSMISSION SYSTEM TRANSFORMERS AND REGULATORS

Transmission system transformers on the Bulk Electric System are rated individually. This section describes the methodology to determine normal and emergency ratings (MVA ratings) of transformer in summer and winter. Corresponding Ampere ratings according to nominal operating voltage are also provided in the Engineering single line diagram.

There are two normal ratings (MVA) for each transformer:

a. Summer Normal Rating (at 30 degree Ambient temperature)
    - The maximum rating shown on the transformer nameplate

b. Winter Normal Rating (at 0 degree Ambient temperature)
    - The maximum winter rating shown on the nameplate
    - For transformer without individual winter rating on the nameplate, the winter rating will be 1.1875 times the maximum normal summer rating on the nameplate as per Section 6.4 of IEEE Standard C57.91, IEEE Guide for Loading Mineral-Oil-Immersed Transformers and Step-Voltage Regulators.

BC Hydro uses Normal Ratings (summer and winter) as Emergency Ratings except for those transformers for which T&D System Operations (TDSO) makes requests for loading analysis. Then Real Time Rating Studies will be conducted to determine the Emergency Ratings of such transformers.

Both summer and winter have two Emergency Ratings (30-minutes and 8 hours period) which are defined below:

- 30-minutes emergency rating: Transformer load can exceed Normal Rating for a maximum period of 30-minutes provided that the hottest-spot temperature in this period does not exceed 140 degree C.
- 8 hours period emergency rating: Transformer load can exceed Normal Rating for a maximum period of 8 hours provided that the hottest-spot temperature in this period does not exceed 130 degree C.

Voltage Regulator only has one rating as stated in the nameplate. Emergency Rating is equal to the Normal Rating.

For transformers and voltage regulators which have asset health issues or major components replacement that might impact their stated ratings, Rating Studies will be performed to reconfirm the ratings and all changes will be updated in the facility rating engineering records.

4 SHUNT REACTORS

Shunt reactors in 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. They are specified, designed and built for use at all system voltage levels to which they will be subjected and are used by operators to lower system operating voltages. The Normal Ratings for BC Hydro shunt reactors are taken from the manufacturers' nameplates.

5 INSTRUMENT TRANSFORMERS

Instrument transformers are rated according to CAN/CSA-C60044 Parts 1 to 6, Standard for Instrument Transformers.

The ratings of instrument transformers are as shown on manufacturers' nameplates. BC Hydro does not operate instrument transformers above their nameplate rating; therefore, Emergency Ratings are the same as Normal Ratings.

6 CIRCUIT BREAKERS

BC Hydro specifies high voltage circuit breakers based on the rated maximum voltage, short-circuit interrupting current, rated continuous current, interrupting time, lightning impulse withstand, transient recovery voltage withstand, ambient temperature conditions (-30°C or -50°C to +40°C), seismic withstand and mechanical endurance.

BC Hydro specifications for circuit breakers are in accordance with the ANSI/IEEE C37 series Standards, including C37.06 -2000 "Symmetrical Current Basis" and the IEC 62271 series Standards for circuit breakers. Their Normal Ratings are as shown on the individual Circuit Breaker nameplates.
BC Hydro does not operate circuit breakers above their nameplate rating; therefore, Emergency Ratings are equal to Normal Ratings.

7 DISCONNECT SWITCHES

Disconnect switches in the Bulk Electric System are mainly used for isolation of individual equipment items, transmission lines and buses for operation and maintenance.

Disconnect switches are rated in accordance with the ANSI/IEEE C37 series Standards. The Normal Rating for BC Hydro disconnect switches is as shown on the manufacturer's nameplate. BC Hydro does not operate switches above their nameplate ratings therefore Emergency Ratings are equal to the Normal Ratings.

8 SHUNT CAPACITORS

Shunt capacitors at BC Hydro are specified and rated according to:

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

Shunt capacitors are specified and designed for the full range of system voltage conditions to which they will be subjected. The Normal Rating for BC Hydro shunt capacitors is as shown on the manufacturer's nameplate.

9 SERIES CAPACITORS

Transmission series capacitors are specified and rated according to:

IEEE 824	Standard Requirements for Series Capacitors in Power Systems
IEC 60143	Series Capacitors for Power Systems

IEEE C37.116 Guide for Protective Relay Application to Transmission-Line Series Capacitor Banks

Transmission series capacitors are rated per their specifications. The Normal and Emergency Rating for BC Hydro transmission series capacitors is given on the manufacturer's nameplate and/or operating manual.

10 STATIC VAR COMPENSATORS

Transmission Static VAR Compensators (SVCs) are specified and rated according to IEEE 1031, Guide for the Functional Specification for Transmission Static VAR Compensators.

Transmission 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 are considered when specifying an SVC. The Normal and Emergency Ratings for BC Hydro transmission SVCs are taken from the manufacturer's nameplate and/or its operating manual.

11 STATIC SYNCHRONOUS COMPENSATORS

Transmission Static Synchronous Compensators (STATCOMs) are specified and rated according to IEEE 1052, Guide for Specification of Transmission Static Synchronous Compensator (STATCOM).

Transmission STATCOMs are specified, designed, and applied for use at the full range of normal system voltage conditions and ranges to which they will be subjected. The Normal Ratings for BC Hydro transmission STATCOMs are taken from the manufacturer's nameplate which is based on the equipment's V-I characteristics. This information is shown in the manufacturer's operating manual.

12 SYNCHRONOUS CONDENSERS

The BC Hydro transmission system uses synchronous condensers to provide reactive power compensation and improve the stability of the system. Their Normal Ratings are shown on the manufacturers' nameplates. BC Hydro does not operate synchronous condensers above their nameplate rating, and the Emergency Ratings are equal to the Normal Ratings. IEEE C50 Standards are also used where applicable.

13 LINE TRAPS

Line Traps, also called Wave traps, are specified and rated according to ANSI C93.3, Requirements for Power-line Carrier Line Traps.

The Normal Ratings for BC Hydro line traps are taken from the manufacturers' nameplates. BC Hydro does not operate line traps above their Normal Ratings. Therefore, Emergency Ratings are equal to the Normal ratings.

14 PROTECTION, CONTROL AND MONITORING (SECONDARY CONNECTED) DEVICES

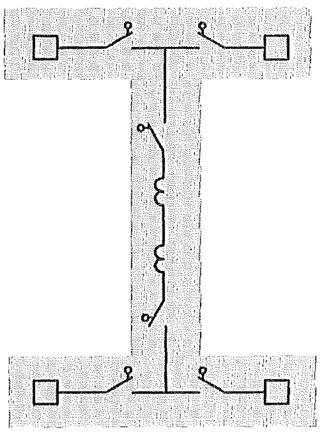
BC Hydro secondary connected device ratings are equal to, or greater than the associated instrument transformer ratings. Relay settings for all transmission lines follow NERC PRC-023-4, Transmission Relay Loadability.

15 REVISION NOTES

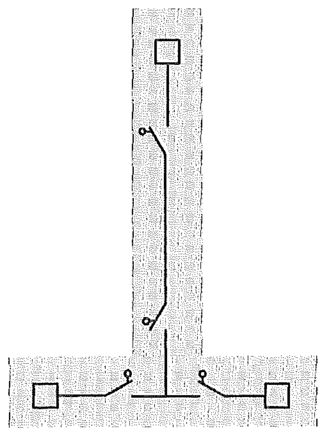
Revision	Date	Revision Description
0	31 Aug 2012	Original issue.
1	30 Aug 2013	Annual review: Section 1, grammar and language changes; Section 6, updated with new standard; Section 16, updated with language referring to secondary device ratings.
2	31 Dec 2014	Annual review; no changes.
3	30 Dec 2015	Annual review; no changes.
4	30 Dec 2016	Annual review; no changes.
5	30 Mar 2018	Annual review: Section 2, updated with updated standard version; Section 3, removed Distribution station and transformer information; Section 7, removed references to general standards relating to Circuit Breakers; Section 8, removed references to general standards relating to Switches; Section 10, updated general formatting.
6	19 Apr 2019	Reformatted standard and added facility descriptions to Section 1.
7	3 June 2020	Revised station facility description, minor edits to Section 2, deleted section on Series Reactors, Sections 2-14 re-written, Section 15 edit to referenced NERC standard, inserted signature block and revised facility examples.
8	25 Nov 2020	Section 1, more details on station facilities and the record of ratings evidence. Included the exception of line terminal breaker which are not part of BES line; Section 2, minor revision to emergency rating description; Section 3, more details on the determination of transformer ratings; Sections 3 to 14, removed last paragraphs of these sections with description added to Section 1; removed section on bus conductors, fittings and attachments rating methodology.

APPENDIX A – FACILITY EXAMPLES

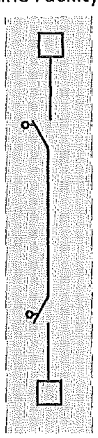
Line Facility



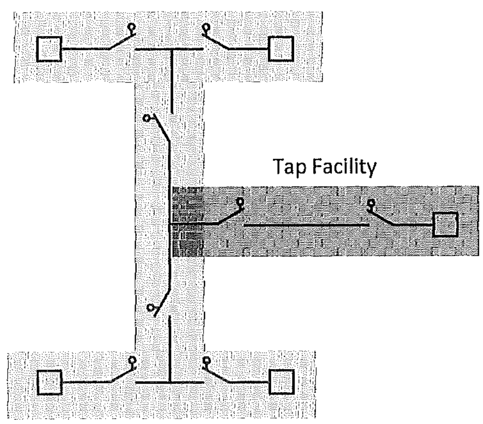
Line Facility

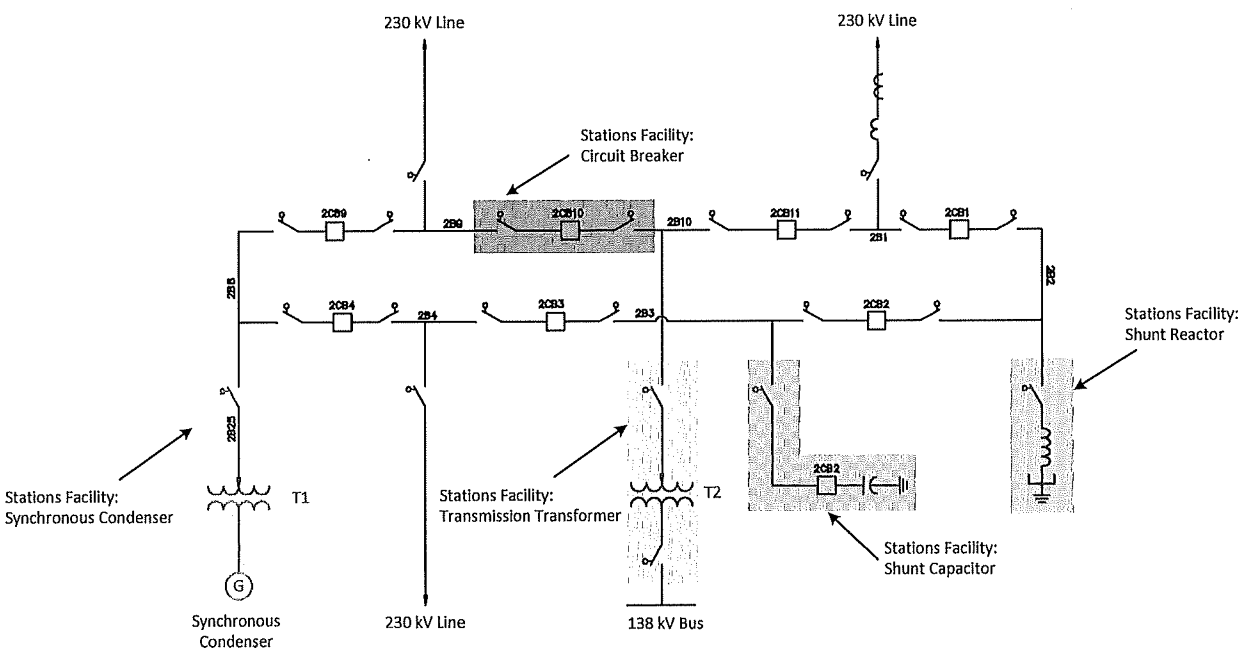


Line Facility



Line Facility




230 kV Line
230 kV Line
Stations Facility:
Circuit Breaker
2CB9
2B9
2CB10
2B10
2CB11
2B1
2CB1
2B5
2B2
2CB4
2B4
2CB3
2B3
2CB2
Stations Facility:
Shunt Reactor
2B25
Stations Facility:
Synchronous Condenser
T1
Stations Facility:
Transmission Transformer
T2
2CB2
Stations Facility:
Shunt Capacitor
G
Synchronous
Condenser
230 kV Line
138 kV Bus