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This document is due for review in 2014.

Revision	Description	Prepared By	Approved By	Date
1	Annual review	C. J. McWhirter	D. J. Papadoulis	30 August 2013
0	Initial Issue	C. J. McWhirter	D. J. Papadoulis	31 August 2012

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 may contain one or more of these elements. Any piece of equipment will have an individual rating; the facility's rating will equal the most limiting equipment rating.

Sections 2 through 16 describe how the ratings for each equipment type are developed.

2 TRANSMISSION LINES

Transmission Line Facilities are comprised of all the overhead and underground transmission lines that interconnect the generating stations, the transmission substations, the distribution substations, and the 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. Circuit ratings are based upon the section of the circuit 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 tap loading does not have to be considered. The means of determining a segments ratings, 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

In cases where emergency ratings are employed, the same criteria as discussed under Normal Rating Criteria are utilized, except that the conductor maximum temperature is in excess of the normal continuous rating. 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 Industry Standards

Overhead transmission line ratings at BC Hydro are established with the methodology described in the CSA Standard for Overhead Systems (CSA C22.3 No.1-01), the IEEE Standard for Calculating the Current-Temperature of Bare Overhead Conductors (IEEE Standard 738-2006) and 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 738-2006). 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" published in August 2006.

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 5 °C.

c Wind Speed
BC Hydro's current ampacity rating criteria based on the geographical area and the metrological data.

d Load Conditions
Snow load: based on the geographical area and the metrological data.
High temperature load: 90 °C on most BC Hydro transmission lines.

e Maximum continuous conductor operating temperatures
These are established based on operating experience and IEEE 1283-2004, 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 operating temperature is the upper limits to control conductor damage due to elevated temperature operation.

2.2 Underground Transmission Cable

2.2.1 Industry Standards

The two basic references used to determine the steady-state ratings are IEC Standard 287 (1982-1995), and classic paper by Neher-McGrath (1957). The corresponding methods for transient analyses are the IEC Standards IEC 60853-1 (1985), the IEC 60853-2 (1989) and Neher (1964).

The steady-state and transient ratings are calculated using CYME software. The computation engine of the software is based on the above referenced IEC 287 and IEC 60853 standards.

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-hour 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 CS4-93 (AEIC CS4-93 Specifications for Impregnated Paper Insulated Low and Medium Pressure Self Contained Liquid Filled Cable). Similarly, the governing temperatures limits for XLPE cables and accessories are described in the AEIC CS9-06 (Specifications for Extruded Insulation Power Cables and Their Accessories Rated 46kV through 345kV).

2.2.3 Rating Algorithms

For calculating the predicted conductor temperature and thus the allowable operating ampacity, BC Hydro uses the algorithms based on the International Electrotechnical Commission (IEC) standard IEC 60287 series. On rare occasion BC Hydro may also use the 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 such as ALGOR is used to compute their impact on ratings.

2.2.4 Acceptable Rating Methods

BC Hydro use the above algorithms in the following ways to rate cables:

a By utilizing CYMCAP software (from CYME International Inc) or Electric Power Research Institute's ACE software suite. These software packages utilize both the Neher-McGrath and IEC 60287 methods.

b To verify cable manufacturer's ampacity calculations.

c Conditions not adequately modeled by software may be rated using other calculation techniques.

2.2.5 Design Parameters

The design parameters used in establishing cable ratings for a given cable type and cable configurations can be found in BC Hydro standard ES-42 and 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 23 °C and 15 °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 1.0.

e Cable Depth
This is based on the proposed route profile. Generally, the cables are placed in a 2X2 concrete encased ductbank configuration and the centre-line of this ductbank configuration is assumed to be 1. 5m 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 circuit 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 TRANSFORMERS

Transmission system transformers on the Bulk Electric System are rated on an individual basis. Transformer emergency ratings at BC Hydro are established with the following methods:

a Application of Standard IEEE C57.91, Guide for Loading Mineral-Oil Immersed Power Transformers Rated in Excess of 100 MVA (65 °C Winding Rise).

b Limitations of the transformer bushings as established and evaluated by the original bushing manufacturer or by bushing nameplate rating. BC Hydro’s specifications require that the bushings are not the limiting factor to load a transformer.

c Limitations of the loading capability of on-load tap changers and de-energized tap changers (if applicable).

General guidelines for determining overloading rating of transformers are shown below.

3.1 Multiple Transformer Distribution Stations, Transformer Winter Loading

With the past change in transformer ratings to a 65 °C rated temperature rise from the formerly used 55 °C rated temperature rise, the loading capability of transformers has been reduced. This is because physically, less copper is required for a transformer rated for a 65 °C rise to achieve a specific rating than a similarly rated transformer rated for a 55 °C rise.

At 0 °C ambient temperature, the most restrictive loading limit for a 110 °C + 10 °C = 120 °C hot spot temperature limit on the BC Hydro system is for an ONAN/ONAF/ONAF transformer, where the load limit is 131%.

Because the BC Hydro substation peak load typically occurs at below 0 °C, a slightly higher loading should be possible.

For a transformer in multiple outdoor air-cooled transformer distribution stations, the transformer loading capacity will be taken as 133% of the fully forced cooled rating.

3.2 Multiple Transformer Distribution Stations, Transformer Summer Loading

At an ambient temperature of 30 °C, the loading limit for ONAN/ONAF/ONAF transformers rated for a 65 °C temperature rise is 109% for a 120 °C hot spot temperature limit.

Because some of the stations in the BC Hydro system may exceed an average temperature of 30 °C during the summer peak, a slightly lower loading will be used.

For a transformer in multiple outdoor air-cooled transformer distribution stations, the transformer loading capacity will be taken as 105% of the fully forced cooled rating.

3.3 Single Transformer Distribution Stations, Transformer Loading

For single transformer distribution stations, the transformer will see the entire peak load year after year. Therefore, to be conservative to preserve equipment life, the rating will be considered for a 110 °C winding temperature hot spot. For a 65 °C temperature rise rated transformer, the rated loading limit at an ambient temperature of 0 °C is 123% for an ONAN/ONAF/ONAF transformer. At 30 °C ambient temperature, the rated loading limit is 101%.

For a transformer in a single transformer distribution station, the winter loading limit will be taken as 120% of the fully forced cooling rating. The summer loading limit will be taken as the fully forced cooling rating.

3.4 Transmission Stations, Transformer Loading

For transmission system substations, the transformers do not see the same varying magnitudes of intra-day load variation as distribution transformers experience. Therefore, in accordance with IEEE and CSA standards, the maximum winter loading limit will be the fully forced cooling rating plus 0.75% per degree Celsius that the ambient temperature is below 25 °C. Historically, the temperature based overload capacity has only been taken to a temperature of 0 °C, and this practice will remain used as a planning limit.

For system transformers, the winter loading limit will be taken as 118.75% of the fully forced cooling rating. The summer loading limit will be taken as the fully forced cooling rating.

4 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 BC Hydro shunt reactors are rated per the manufacturer's nameplate. BC Hydro does not have ratings above normal for shunt reactors therefore no Emergency Ratings are provided as they would be equal to the Normal Ratings.

Other associated power system equipment connected to the reactor such as breakers, switches, bus work 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.

5 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 and ANSI C57.99, Guide for Loading Dry-Type and Oil-Immersed Current-Limiting Reactors.

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

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.

6 INSTRUMENT TRANSFORMERS

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

BC Hydro rates transmission instrument transformers according to manufacturers' specifications with continuous ratings shown on the nameplate. BC Hydro does not have emergency ratings for instrument transformers; therefore emergency ratings will be identical to continuous ratings. BC Hydro maintains a stock of critical instrument transformers for emergencies.

7 CIRCUIT BREAKERS

BC Hydro specifies the AC High Voltage circuit breakers based on the operating voltage, short-circuit interrupting current, 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.

The specifications are principally in accordance with ANSI/IEEE Standards C37 series, “Symmetrical Current Basis” and IEC Standards 62271 series. These ratings are indicated on the individual Circuit Breaker nameplate. The following standards are referenced in the breaker specifications:

ABSI/IEEE C57.19.00	General Requirements and Test Procedures for Outdoor Power Apparatus Bushings
ANSI C29.1	Test Methods for Electrical Power Insulators
ANSI C37.06	Preferred Ratings and Related Required Capabilities for AC High Voltage Circuit Breakers Rated on a Symmetrical Current Basis
ANSI/ASME B1.1	Unified Inch Screw Threads
ANSI/ASME B1.20.1	General Purpose Pipe Threads
ANSI/ASME B16.1 & ANSI/ASME B16.5	Pipe Flanges and Flanged Fittings
ANSI/IEEE C37.010	Application Guide for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis
ANSI/IEEE C37.011	Transient Recovery Voltage for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis
ANSI/IEEE C37.012	Capacitance Current Switching of AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis
ANSI/IEEE C37.04	Rating Structure for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis
ANSI/IEEE C37.081	Guide for Synthetic Fault Testing of AC High-Voltage Circuit Breakers Rated on a Symmetrical Basis
ANSI/IEEE C37.09	Test Procedure for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis
ANSI/IEEE C37.100	Definitions for Power Switchgear

ANSI/IEEE C37.90.1	Surge Withstand Capability (SWC) Tests for Protective Relays and Relay Systems
ASME B31.1	Power Piping
ASME PTC9	Performance Test Code for Displacement Compressors, Vacuum Pumps and Blowers
ASME	Boiler and Pressure Vessel Code – VIII Pressure Vessels
ASTM A182	Standard Specification for Forged or Rolled Alloy-Steel Pipe Flanges, Forged Fittings and Valves and Parts for High-Temperature Service
ASTM A269	Standard Specification for Seamless and Welded Austenitic Stainless Steel Tube for General Service
ASTM A312	Standard Specification for Seamless and Welded Austenitic Stainless Steel Pipes
ASTM B302	Standard Specification for Threadless Copper Pipe
ASTM D2472	Standard Specification for Sulphur Hexafluoride
CAN/CSA C1264-99	Ceramic Pressurized Hollow Insulators for High-Voltage Switchgear and Controlgear
CAN/CSA-C50052-99	Cast Aluminum Alloy Enclosures for Gas-Filled High-Voltage Switchgear and Controlgear
CAN/CSA-C50064-99	Wrought Aluminum and Aluminum Alloy Enclosures for Gas-Filled High-Voltage Switchgear and Controlgear
CAN/CSA-C50068-99	Wrought Steel Enclosures for Gas-Filled High-Voltage Switchgear and Controlgear
CAN/CSA-C50069-99	Welded Composite Enclosures of Cast and Wrought Aluminum Alloys for Gas-Filled High-Voltage Switchgear and Controlgear
CAN/CSA-C50089-99	Cast Resin Partitions for Metal-Enclosed Gas-Filled High-Voltage Switchgear and Controlgear
CAN3-C13-M	Instrument Transformers
CAN3-C308-M	The Principles and Practice of Insulation Coordination
CSA B51-M	Boiler, Pressure Vessel, and Pressure Piping Code
CSA C50	Insulating Oil, Electrical for Transformers and Switches

EEMAC GL1-3	Power Transformer and Reactor Bushings
IEC 60060	High-Voltage Test Techniques
IEC 60233	Tests on Hollow Insulators for Use in Electrical Equipment
IEC 60376	Specification and Acceptance of New Sulphur Hexafluoride
IEC 60427	Report on Synthetic Testing of High Voltage Alternating Current Circuit Breakers
IEC 60480	Guide to the Checking of Sulphur Hexafluoride (SF6) Taken from Electrical Equipment
IEC 60694	Common Clauses for High-Voltage Switchgear and Controlgear Standards
IEC 61264	Ceramic Pressurized Hollow Insulators for High-Voltage Switchgear and Controlgear
IEC 61462	Composite Insulators – Hollow Insulators for Use In Outdoor and Indoor Electrical Equipment
IEC 62271-100	High Voltage Alternating Current Circuit Breakers
IEC 62271-102	Alternating Current Disconnectors and Earthing Switches
IEC 62271-301	High-Voltage Alternating Current Circuit-Breakers: Inductive Load Switching
IEC 62271-302	Guide to Testing of Circuit Breakers with Respect to Out-of-Phase Switching
IEC TR2 61233	High-Voltage Alternating Circuit-Breakers – Inductive Load Switching
IEEE C37.015	IEEE Application Guide for Shunt Reactor Switching
IEEE 693	IEEE Recommended Practice for Seismic Design of Substations

The Nominal Rating for BC Hydro transmission circuit breakers is as shown on the manufacturer's nameplate. The seismic withstand of the transmission circuit breakers is "High" in accordance with IEEE 693 and manufacturers must prove this rating through actual testing. The mechanical endurance rating for BC Hydro circuit breakers is M2 (successfully withstanding 10,000 mechanical operations) in accordance with IEC 62271-100. In addition, shunt reactor switching circuit breakers must be rated for 5,000 shunt reactor switching operations with no maintenance of the interrupting parts. Any grading capacitors must be suitable for continuous operation at maximum operating voltage with the breaker left in open position. The transient recovery voltage (TRV) withstand requirements are rated "High" or "Medium" as per ANSI C37.06 plus a special TRV envelope described in BC Hydro's technical specification for High Voltage circuit breakers.

BC Hydro follows a stringent qualification process for the acquisition, installation, commissioning and maintenance of transmission circuit breakers. All circuit breaker manufacturers must submit with their tenders a full dossier of all type tests performed on the specific circuit breakers. The type test reports are evaluated by BC Hydro or their agent (BC Hydro Engineering). Tender review meetings are held to clarify all aspects (technical and commercial) of the tendered equipment. Once purchase orders are issued, the manufacturers submit drawings for review and approval, and Design Review meetings are conducted at the manufacturers' plants for new circuit breaker types. The circuit breakers must pass all production tests specified and some of these are witnessed and inspected prior to shipping to site. BC Hydro performs commissioning tests before placing the equipment in service. Finally, a maintenance standard exists or is set up for every type of circuit breaker in BC Hydro transmission system. The maintenance standard specifies the maintenance tasks, the maintenance intervals, the acceptable values for various maintenance parameters (e.g. contact resistance, timing, Doble results if applicable, pressures, etc.). These values are then entered into the computerized Work Management system via hand-held devices, for future reference.

8 SWITCHES

A similar acquisition, commissioning and maintenance process to that for circuit breakers is applicable to BC Hydro disconnect switches. The following standards are used to rate high voltage switches:

ANSI C37.32	High-Voltage Switches, Bus Supports, and Switch Accessories – Schedules of Preferred Ratings, Construction Guidelines and Specifications
ANSI C37.33	Switchgear – High Voltage Air Switches – Rated Control Voltages and their Ranges
ANSI/ASME B1.1	Unified Inch Screw Threads
ANSI/IEEE C37.90.1	Surge Withstand Capability (SWC) Tests for Protective Relays and Relay Systems
ASTM B633	Specification for Electrode Deposited Coatings of Zinc on Iron and Steel
CAN/CSA-C156.1-M	Ceramic and Glass Station Post Insulators
CSA C22.1	Canadian Electrical Code, Part I, Safety Standard for Electrical Installations
IEEE C37.30	Definitions and Requirements for High Voltage Air Switches, Insulators and Bus Supports
IEEE C37.34	Test Code for High Voltage Air Switches
IEEE No. 4	IEEE Standard Techniques for High Voltage Testing
IEEE 693	IEEE Recommended Practice for Seismic Design of Substations

Transmission switches are rated in accordance to the manufacturer's nameplate. The Normal Rating for BC HYDRO transmission switches is as shown on the manufacturer's nameplate. BC HYDRO does not have ratings above normal for transmission switches therefore no Emergency Ratings are provided as they would be equal to the Normal Ratings.

9 SHUNT CAPACITORS

Transmission shunt capacitors at BC Hydro 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 and 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 conditions and ranges to which they will be subjected. The Normal Rating for BC Hydro transmission shunt capacitors are rated per the manufacturer's nameplate. BC Hydro does not have ratings above normal for shunt capacitor banks therefore no Emergency Ratings are provided as they would be equal to the Normal Ratings.

Other associated power system equipment connected to the bank such as breakers, switches, buswork 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.

10 SERIES CAPACITORS

Transmission series connected capacitors are specified and rated according to IEEE 824, IEEE Standard Requirements for Series Capacitors in Power Systems and ANSI/IEEE C37.116, Guide for Protection Relaying Applications to Transmission Connected Series Capacitors.

Transmission series capacitors are rated per the manufacturer's specifications. The Normal Rating for BC Hydro transmission series capacitors is given on the manufacturer's nameplate and instruction books. BC Hydro specifies ratings above normal for series capacitors consistent with power system requirements in the form of a normal rating and a 30 minute rating. System swing and transient requirements are carefully coordinated with system requirements for each individual location.

Other associated power system equipment connected to the series capacitor such as breakers, switches, buswork 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.

11 STATIC VAR COMPENSATORS

Transmission class Static VAR Compensators (SVCs) are specified and rated according to IEEE 1031, 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 BC Hydro transmission class SVCs are rated per the manufacturer's nameplate. BC Hydro 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.

12 STATIC SYNCHRONOUS COMPENSATORS

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

Transmission class STATCOMS 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 STATCOM. The Normal Rating for BC Hydro transmission class STATCOMs are rated per the manufacturer's nameplate. BC Hydro STATCOMs 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 STATCOM, such as breakers, switches, buswork and relay settings are designed not to be limiting elements for the operation of the device.

13 DC TERMINALS

BC Hydro HVDC systems are specified and rated according to:

IEEE 1204	Guide for Planning DC Links Terminating at AC Locations Having Low Short-Circuit Capacities
IEEE 1531	Guide for Application and Specification of Harmonic Filters
IEEE 1227	Guide for the Measurement of DC Electric-Field Strength and Ion Related Quantities
IEEE 1031	Guide for the Functional Specification for Transmission Static VAR Compensators
IEEE 857	Recommended Practice for Test Procedures for High-Voltage Direct-Current Thyristor Valves

IEEE 1124 Guide for the Analysis and Definition of DC-Side Harmonic Performance of HVDC Transmission Systems

BC Hydro HVDC systems are specified, designed, and applied for the full range of normal system voltage, operational conditions and limits to which they will be subjected to. Harmonic impedance data, existing AC system harmonics and self-generated harmonics are also considered when specifying an HVDC system. The Normal Rating for BC Hydro HVDC system is rated per the manufacturer's nameplate. BC Hydro HVDC systems are specified with some over and under voltage, short/long time current carrying, under/over frequency, real/reactive power capabilities depending on the application and therefore possess some emergency ratings depending on the desired performance and intended purpose. The systems are specified with the specific configurations. Some of these are monopolar, bipolar with or without metallic ground return. The systems can be specified to be of either line-commutated current sourced converter or self-commutated voltage sourced converter types. The switching technologies, e.g. thyristor, IGBT, etc. including valve design may be specified as required.

Other associated power system equipment connected to the HVDC systems may include converter/inverter transformers, synchronous condensers, SVCs, AC and DC harmonic filters, smoothing reactors, DC capacitors, ground electrodes, MOVs, arresters, switching equipment such as breakers, switches, interrupters, etc., integrated communications and controls systems, protection systems for AC, HVDC, auxiliary components, etc.

14 LINE TRAPS

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

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

15 BUS CONDUCTORS, FITTINGS AND ATTACHMENTS

The electrical conductivity of various materials used in buswork in the BC Hydro system is listed in Table 1 below. Although hard-drawn copper with 98% conductivity is still used in some applications, aluminum alloy is the preferred material.

15.1 Material

For electrical applications, aluminum alloys are used because they have good mechanical strength to withstand the stresses caused by short circuits, wind, sleet and thermal expansion and still maintain high enough conductivity to minimize power loss and temperature rise under overload. The most commonly used aluminum alloys in electrical applications are:

a Aluminum 1350 H12 for wire and bus conductors - this wrought aluminum alloy with 99.50% purity is characterized by excellent corrosion resistance, high thermal and electrical conductivity, limited mechanical properties and excellent workability.

b Aluminum 6101 T6 for wire and bus conductors - this heat-treated wrought aluminum has considerably higher yield strength and better creep resistance than 1350, without significant reduction in conductivity.

c Aluminum A356 for connector fittings - these cast alloys have high mechanical strength and adequate conductivity. They are suitable for bolted connections and are used in all stock connectors in the BC Hydro system.

Table 1 - Properties of Aluminum Alloys Used for Buswork

Property	Alloy and Temper		
	1350 H12	6101 T6	A356
Electrical conductivity at 20 °C, percent IACS	61-62	57	41
Thermal conductivity at 20 °C, W/in./°C	5.9 - 6.0	5.6	4.1
Tensile strength at 20 °C, ksi minimum ultimate minimum yield	 12 8	 29 25	 38 27
Typical Yield strength (0.2% extension), ksi	12	28	28
Melting point, °C	657	654	615
Coefficient of linear thermal expansion per °C	0.000023	0.000023	0.0000225
Modulus of elasticity, ksi	10	10	10.5

For design purposes, in conjunction with other recommendations described in this methodology, a current density of 0.27 A/mm^2 (175 A/in.^{2}), calculated on the basis of contact surface, should be used to determine the required minimum contact area for both cylindrical and flat connectors.

Since flat terminal pads require design uniformity in order to ensure compatibility between the connector pads and the corresponding equipment terminals, their size and hole configurations are based on NEMA Standards Publication CC1.

Bolted aluminum connectors are chosen according to both their electrical and mechanical requirements and whenever practicable, tested in accordance with CSA C57. The body material shall be aluminum 6101-T6 or other alloys of equivalent or higher mechanical strength.

15.2 Ambient Air Temperature

Ambient air temperature affects the electrical and physical properties and operating characteristics of material and equipment.

For general station design the maximum ambient air temperatures are 35 °C for the southern interior of the province and 30 °C for the rest of the province. These values are based on the National Building Code of Canada 2.5% temperatures. Minimum ambient air temperatures are -30 °C for the Lower Mainland and Vancouver Island and -50 °C for the rest of the province.

For major equipment specification the maximum ambient temperature is 40 °C throughout the province.

15.3 Mechanical Strength Requirements

Although written specifically for aluminum conductor the mechanical strength requirements and other mechanical aspects of the design of rigid outdoor aluminum bus work are also generally applicable to conductors made from copper and other materials.

15.3.1 Conductor Fibre Stress

Fibre stress in the aluminum conductor shall be limited to 100 MPa. This value is based on an ultimate tensile strength for 6101-T6 aluminum alloy of about 200 MPa with an applied safety factor of 2.0.

Where welds are located in high stress areas fibre stress must be limited to 75 MPa. Welds in high stress areas shall therefore be avoided. This limitation does not apply to welded bus couplings which use an internal sleeve behind the weld area.

15.3.2 Insulator Cantilever Force

Cantilever force at the top of bus support insulators is limited to 40% of the rated cantilever strength of the insulator. This provides a safety factor of 2.5 as recommended by insulator manufacturers.

15.3.3 Radial Ice

A radial coating of ice on the bus conductor increases the bus mass and cross section thus increasing the gravitational and wind force respectively.

A radial ice thickness of 12.7 mm is used for buswork design. Radial ice accretion on insulators is not significant for buswork design. Radial ice accretion is not considered in the design of structures.

15.3.4 Short Circuit Currents

The interaction of short circuit currents in two or more bus phases produces lateral forces on the buswork. The buswork mass may include radial ice and damping cable.

15.3.5 Seismic Activity

Ground accelerations due to earthquakes impose dynamic forces which must be considered in bus design.

15.3.6 Design Load Combinations

Two combinations of the influencing factors have been chosen as representing the most likely and onerous combinations for calculating mechanical strength requirements of the buswork:

a Gravity, reference wind pressure of 385 Pa (gust factor 1.0), 12.7 mm radial ice and short circuit forces
b Gravity and reference wind pressure of 400 Pa or 600 Pa times a gust factor of 2.0

Shape and exposure factors must be applied for both of the above combinations. The adequacy of supporting structure and foundation design is the responsibility of the Civil and Mechanical Design Department. Seismic design is considered independently of the design load combinations.

15.4 Aeolian Vibration

Horizontal laminar air flow in a direction normal or nearly normal to the longitudinal axis of the bus conductor produces alternating vertical forces on the conductor. This phenomenon is known as Aeolian excitation. If the excitation frequency is close to the natural frequency of the conductor arrangement, potentially destructive vibrations may occur on the conductor.

The conductor length is the distance between points of support. These may be insulator clamps, equipment terminals, interphase insulators, A-frames or rigid drops. Since end conditions cannot be precisely defined, the more onerous condition should be determined. Aeolian vibration on tubular bus is generally controlled by installing damping cable inside the tube. To be effective, the damping cable must be very flexible and have a mass between 10% and 30% of the bus mass. The cable must be vinyl or plastic covered to reduce audible noise.

15.5 Thermal Expansion

Thermal expansion of the bus conductor must be accommodated to avoid overstressing the buswork components or connected equipment components.

15.6 Bus Vertical Deflection

For aesthetic reasons, the ratio of conductor vertical deflection to span length is limited to 0.00667. Radial ice loading is not considered in the calculation.

16 PROTECTION, CONTROL AND MONITORING (SECONDARY CONNECTED) DEVICES

BC Hydro secondary connected device ratings are equal to, or greater than the associated instrument transformer ratings (see Section 6). Relay settings for all transmission lines follow NERC PRC-023-1 guidelines for relay loadability.

17 REVISION NOTES

Revision 0: Original issue.
Revision 1: Annual review in 2013
Section 1, grammar and language changes
Section 6, updated with new standard
Section 16, updated with language referring to secondary device ratings