60 kV to 500 kV

Technical Interconnection Requirements

For

Power Generators

Revision: 2.1.1

Effective Date: September 22, 2025

Disclaimer

This document provides general technical interconnection requirements of BC Hydro for proponents that wish to connect a Power Generating Facility (**PGF**) to the BC Hydro System.

This document is not intended as a design specification nor an instruction manual for connecting a PGF to the BC Hydro System. Persons using the information included in this document do so at their own risk. BC Hydro does not accept any liability of any kind arising in any manner out of the use by a person of any information, product or process disclosed, described or recommended in this document, nor does BC Hydro accept any liability arising out of reliance by a person upon any information, statements recommendations or requirements contained or listed in this document.

A proponent, its employees and agents are solely responsible at all times for the design, construction and operation of the PGF. BC Hydro does not, implicitly nor expressly, represent, guarantee or warrant to any person:

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(b) the intellectual or other property rights of any person or party in, or
(c) the merchantability, safety or fitness for purpose of,

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The information contained in this document is subject to change and may be revised at any time. BC Hydro should be consulted in case of doubt on the current applicability of any item.

Revision History

R 0.0	October 2008	Initial Release
R 0.1	December 2009	Updated Revenue Metering Link
R 1.0	April 2010	Updated Sections 5.4.1; 5.4.3; 5.4.4; 8.5; Figure A2 link; Appendix C (Figures C1 & C2)
R 1.1	July 2010	BCTC integration into BC Hydro No technical changes in this revision
R 1.2	September 2011	Added Authors and Approval for NERC Compliance. Minor wording edit in Appendix A, Section A.3.1 Reactive Power Requirements.
R 1.3	February 2012	Updated Section 5.4.4 based on new WECC Governor Droop Setting Criterion (reference: PRC-001-WECC-CRT-1), and correct contact Email address
R 1.4	June 2014	Updated addresses (email and physical) and deleted phone numbers
R 2.0	February 2024	General Revision, updates including inverter-based resources
R 2.1	February 2024	Errata
R.2.1.1	September 2025	Clarifications of FFR & dynamic Var requirements

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Figures and Tables

1. Introduction

BC Hydro has prepared this **60 kV to 500 kV Technical Interconnection Requirements for Power Generators** (**TIR**) to identify general technical requirements for connecting Power Generating Facilities (**PGFs**) to the BC Hydro System between 60 kilovolts (kV) and 500kV. The purpose of this document is to:

a) facilitate compliance and compatibility of the Generator Owner's (GO's) facilities with BC Hydro standards and practices for safe operation, integrity, reliability and power quality of the BC Hydro facilities;

b) provide information to the GO for the planning, design, construction and commissioning of the GO's facilities in order to ensure that impacts to the BC Hydro facilities operation and reliability are acceptable to BC Hydro;

c) facilitate the efficient exchange of information between BC Hydro and the GO relevant to planning, design, construction and operation of the PGF and required to conduct Interconnection Studies as defined in the Open Access Transmission Tariff (**OATT**); and

d) provide the minimum technical requirements the GO's facilities must meet and identify expected system conditions the GO's facilities could encounter while connected to the BC Hydro facilities.

Contractual matters, such as costs, ownership, scheduling, and billing are not the focus of this document. Transmission Service (as defined in the OATT) are not addressed by this document either. All requests for Transmission Service shall be made independent of the interconnection requests pursuant to the terms of BC Hydro's OATT. Please refer to the BC Hydro website for more information on the interconnection process, business practices, contractual matters and Transmission Services:

https://www.bchydro.com/energy-in-bc/operations/transmission.html

https://app.bchydro.com/accounts-billing/electrical-connections/transmission-generator-interconnections.html

This document is subject to change in accordance with industry events and evolving standards. Technical interconnection requirements contained in this document are consistent with BC Hydro's current practices for system additions and modifications. In establishing these requirements, BC Hydro considers the standards, principles, and practices of the following, as may be added to, or amended from time to time:

a) North American Electric Reliability Corporation (**NERC**);

b) Western Electricity Coordinating Council (**WECC**);

c) Northwest Power Pool (**NWPP**),

d) Canadian Standards Association (**CSA**);

e) Institute of Electrical and Electronics Engineers (**IEEE**);

f) American National Standards Institute (**ANSI**);

g) International Electrotechnical Commission (**IEC**);

h) British Columbia Utilities Commission (**BCUC**), including the BC Mandatory Reliability Program; and

i) Good Utility Practice.

BC Hydro reserves the right to take whatever measures are necessary, in its sole discretion, to ensure the safe and reliable operation of the BC Hydro facilities.

The GO shall submit all specifications of its facilities and detailed plans to BC Hydro to enable BC Hydro to conduct the technical review required to grant permission to interconnect the proposed project. The GO shall notify BC Hydro immediately in the event of any modifications to the detailed plans that could impact the performance of the interconnection.

The GO shall communicate any issues with BC Hydro's Transmission Generator Interconnections Office.

BC Hydro
Transmission Generator Interconnections
6911 Southpoint Drive
Edmonds B03
Burnaby, BC V3N 4X8

Email: Transmission.Generators@bchydro.com

The GO will communicate directly with all regulatory and governmental authorities to ensure that the PGF is designed, constructed, operated and maintained in compliance with all applicable standards, statutes, regulations, by-laws and codes.

2. Definitions

Balancing Authority (BA) – the responsible entity that integrates resources, plans ahead of time, maintains load-interchange-generation balance within its balancing authority area, and supports interconnection frequency in real time.

Battery Energy Storage System (BESS) – means a battery system capable of absorbing energy, storing it, and dispatching the energy into the power system, and refers to the system in its entirety, including the main power transformers and switchgears etc. The term does not refer only to the individual storage device or converters themselves.

BC Hydro (BCH) – British Columbia Hydro and Power Authority, a Crown corporation owned by the Province of British Columbia having its head office at 333 Dunsmuir Street, Vancouver, British Columbia V6B 5R3, and for the purposes of this document, references are only to BC Hydro in its transmission role as Transmission Service Provider, Transmission Owner, Transmission Planner, and Transmission Operator etc. Unless explicitly stated, references within this document do not include BC Hydro is its role as Generator Owner or Generator Operator.

BC Hydro System or Transmission System – the transmission system, protection, control and telecommunications facilities owned, operated and maintained by BC Hydro.

BC Mandatory Reliability Program – the BCUC oversight of the NERC Mandatory Reliability Standards adopted for use in BC. Information about the program is posted on the BCUC website: https://www.bcuc.com/WhatWeDo/MRS.

BC Mandatory Reliability Standards (BCMRS) – the NERC Mandatory Reliability Standards adopted by BCUC.

British Columbia Utilities Commission (BCUC) – the British Columbia Utilities Commission is an independent regulatory agency of the Provincial Government that operates under and administers the Utilities Commission Act. The BCUC's primary responsibility is the regulation of British Columbia's natural gas and electricity utilities. BCUC also regulates intra-provincial pipelines and universal compulsory automobile insurance.

Bulk Electric System (BES) – unless modified by the lists specified by NERC, means "all Transmission Elements operated at 100 kV or higher and Real Power and Reactive Power resources connected at 100 kV or higher. This does not include facilities used in the local distribution of electric energy".

Control Centres (Fraser Valley Office [FVO] and South Interior Office [SIO]) – BC Hydro operates two Primary control centres (FVO and SIO) that are functionally identical and are locations from which BC Hydro operates its Transmission System. FVO and SIO also operate the BC Hydro distribution system and generation system. BC Hydro is responsible for meeting all BA responsibilities as defined in NERC and WECC standards for British Columbia.

Extra High Voltage (EHV) – voltage level between 300 kV and 800 kV**.**

Emergency – any condition where, whether by reason of a forced outage or concern for a forced outage, or otherwise, there is an imminent risk of equipment failure, or of danger to BC Hydro or GO personnel, the public or others, or a risk to the security or reliability of the PGF, the BC Hydro System or any other generation, transmission, distribution or other electric system interconnected with the BC Hydro System or the PGF.

Electromagnetic Transient Tool (EMT) – means a proven EMT tool of choice, either EMTP-RV (www.emtp.com) or PSCAD/EMTDC (www.pscad.com).

Fast Frequency Response (FFR) – means rapid adjustments of active power injected into or absorbed from the grid in response to changes in measured or observed frequency during the arresting period of a frequency excursion event to improve the frequency nadir or initial rate-of-change of frequency. FFR capability is a faster response capability to frequency events as opposed to the more traditional and slower primary frequency response (PFR) capability.

For example, "Virtual Inertia Control" in wind turbines is one of the forms of FFR and refers to a technique that boosts the power output of wind turbines for a brief period to provide frequency support and stability to the system. This temporary power boost may be achieved by extracting kinetic energy from the turbine's rotating mass or through other methods.

Generator Interconnection Data Form (GIDF) – The BC Hydro data form required for all new generator interconnections or materially modified interconnections, applicable to all types of generating facilities including all synchronous generators, all IBR generating facilities, and other asynchronous generators. There are two versions of the GIDF form; one for Feasibility Studies, and one for System Impact Studies. The GIDF is available on the BC Hydro website:

https://app.bchydro.com/accounts-billing/electrical-connections/transmission-generator-interconnections.html.

Generator Owner (GO) or Interconnection Customer – a legal entity who is a proponent of or an owner of a PGF. The GO may consume all or some of the electric energy produced at the PGF.

Good Utility Practice – means any of the practices, methods and acts engaged in or approved by a significant portion of the electric utility industry during the relevant time period, or any of the practices, methods and acts which, in the exercise of reasonable judgment in light of the facts known at the time the decision was made, could have been expected to accomplish the desired result at a reasonable cost consistent with good business practices, reliability, safety and expedition. Good Utility Practice is not intended to be limited to the optimum practice, method or act to the exclusion of all others, but rather to be acceptable practices, methods or acts generally accepted in the WECC region.

Grid Forming[1]: means an inverter operating mode that enables reliable, stable, and secure operation when the inverter is operating on a part of the grid with few (or zero) synchronous machines along with the possibility of weak or non-existent ties to the rest of the bulk power system.

[1] NERC Reliability Guideline, Performance, Modeling, and Simulations of BPS-Connected Battery Energy Storage Systems and Hybrid Power Plants, March 2021

Hybrid Power Plant (HPP) – means a generating facility that is comprised of generation resources of different technologies (typically including energy storage systems) controlled as a single entity and operated as a single resource behind a single POI. For example, the combination of renewable energy (solar PV or wind) and battery energy storage technologies can form an HPP. This term is different from co-located plants which have more than one plant operated and controlled separately from one another even though they are connected at a single POI.

AC-Coupled BESS Hybrid Plant – means the plant has the BESS and resources converted from DC to AC at each individual inverter and then collectively connected at a common AC collection bus as shown in an example diagram from NERC, Figure I.1 The BESS may be charged either from the renewable generating resources or from the grid.

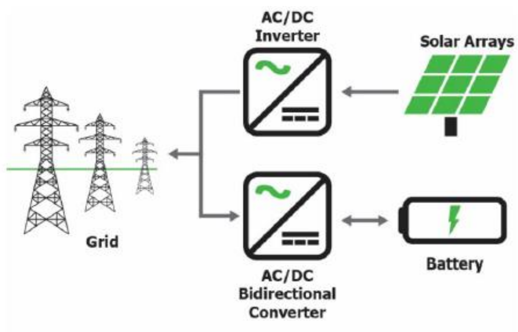


Figure I.1: Illustration of AC-Coupled Hybrid Plant

DC-Coupled BESS Hybrid Plant – means the plant has the BESS and resources collectively connected at a common DC bus which is then converted to AC for connection to the grid as shown in an example diagram from NERC, Figure I.2. The DC to AC inverter can be unidirectional where the BESS can only be charged from the renewable resource. The inversion also could be bi-directional in which case the BESS may be charged from the grid.

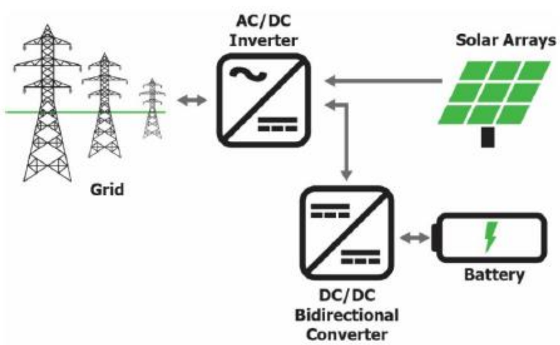


Figure I.2: Illustration of DC-Coupled Hybrid Plant

Inverter Based Resource (IBR Plant) – means any source of electric power that is connected to the Transmission System via power electronic interface, and that consists of one or more IBR unit(s) capable of exporting active power from a primary energy source or energy storage system to the Transmission System. A collector system or a supplemental IBR device operated by a common facility-level controller behind a common POI to achieve the performance requirements of the reliability standards is part of an IBR Plant. However, this term excludes some generating facilities connected by means of a dedicated direct current transmission link.

Majority of IBR generators use the control architectures that primarily rely on using a phase-locked loop (**PLL**) to lock onto the grid phasor and have fast inner-current control loops to regulate the active and reactive current injected by the IBR. These are "grid-following" types of technology. In some rare applications up to date such as islanded operation, the IBR's regulated variables are voltage and frequency rather than current, which is typically referred to as "grid-forming" technology in contrast with "grid-following" one.

Island – means a portion of the Transmission System consisting of load and generation, which has become isolated due to the tripping of Transmission System elements.

Main Transmission System – means the Transmission System facilities operated at 500, 360, 287 and 230 kV and some designated lower voltage transmission lines.

Maximum Power Injection (MPI) – means the maximum amount of power in MW that can be injected into the Transmission System at the POI.

North American Electric Reliability Corporation (NERC) – means the North American Electric Reliability Corporation, whose mission is to ensure the reliability of the bulk power system in North America. To achieve this, NERC develops and enforces reliability standards; assesses adequacy annually via 10-year and seasonal forecasts; monitors the bulk power system; evaluates users, owners, and operators for preparedness; and educates, trains, and certifies industry personnel. NERC is a self-regulatory organization, subject to oversight by the U.S. Federal Energy Regulatory Commission and governmental authorities in Canada.

Maximum Power Output (MPO) – means the maximum possible output from the generator under ideal conditions. For hydro units this is usually at maximum head with the wicket gates fully open.

Materially Modified Interconnections: per OATT, "Material Modification shall mean those modifications that have a material impact on the cost or timing of any Interconnection Request with a later queue priority date or that would affect the reliability or stability of the Transmission System." NERC is in the process to introduce a similar but different term of "qualified changes" to existing generating facilities. In a drafted NERC standard FAC-002-4, it is required in R6 that "each Planning Coordinator shall maintain a publicly available definition of qualified change for the purposes of facility interconnection".

Point of Interconnection (POI) – as defined in the OATT.

Power Generating Facility (PGF) – means a plant/site that is installed for the production and/or storage for later injection of electricity into the Transmission System, and refers to the system in its entirety, including the main power transformers and switchgears etc. This term covers the synchronous generating facilities (such as hydro, gas, biomass plants etc.), and asynchronous generating facilities (such as IBR Plants and induction generating plants etc).

Rated Power Factor – means the generator MVA multiplied by the rated over-excited power factor.

Remedial Action Scheme (RAS) – means an automatic scheme designed to detect abnormal system conditions and take pre-planned, corrective action (other than the isolation of faulted elements) to provide acceptable system performance.

Solar Photovoltaic Energy Resource (Solar IBR) – means any group of one or more IBR units used for converting solar energy to electricity by using photovoltaic technology, which refers to the system in its entirety, including the solar photovoltaic generating panels, the lower voltage collection lines, main power transformers, inverters, controls, and switchgears etc.

Standard Generator Interconnection Agreement (SGIA) – means the interconnection agreement, prescribed by the OATT, between the GO and BC Hydro setting out the contractual obligations of each party in respect of the int4rconnection. The agreement includes provisions relating to facility ownership, operation, dispute mechanisms, and technical requirements, these interconnection requirements are incorporated therein.

State of Charge (SOC) – means a measure of how much energy is stored in the BESS, expressed as a percentage ranging from completely discharged (0%) to fully charged (100%). The SOC affects the ability of the BESS to support the Transmission System to which it is connected, such as voltage support, frequency response, and ramping capability.

Wind Generating Facility (WGF) – means any group of one or more Wind Turbine Generators (**WTG**) used for converting wind energy to electricity, and injecting the electric energy into the BC Hydro System, and refers to the system in its entirety, including the main power transformers and switchgears etc.

Western Electricity Coordinating Council (WECC) – WECC is the organization responsible for coordinating and promoting electric system reliability. In addition to promoting a reliable electric power system in the Western Interconnection, WECC will support efficient competitive power markets, assure open and non-discriminatory transmission access among members, provide a forum for resolving transmission access disputes, and provide an environment for coordinating the operating and planning activities of its members as set forth in the WECC Bylaws.

3. Scope

These technical requirements apply to all new Interconnections or Materially Modified Interconnections including the BC Hydro owned generators to the Transmission System, which is an alternating current (AC) system. The PGFs as defined in Definitions may be connected either directly to the Transmission System or through GO facilities. This document does not cover generating facilities to be connected to the BC Hydro non-integrated system.

The IBR Plants described in this document include wind generating stations (type III and type IV), photovoltaic solar generating stations, BESS and any form of hybrid design that combines at least one variable generation source and one BESS system. However, this excludes some generating facilities connected by means of a dedicated direct current transmission link. Where a GO uses HVDC technology to transfer the power to the POI, it is the GO's responsibility to install adequate equipment compatible with the BC Hydro System for interconnection. As each HVDC has its unique design, additional technical requirements will be determined on a case by case basis at the interconnection study stage.

For the interconnection of a BESS or a pumped storage system, the technical requirements for the plant in power generation mode is addressed in this document. When the plant operates as a load, a separate BC Hydro document: "*Technical Interconnection Requirements For Transmission Voltage Customers for Service at 60,000 to 287,000 Volts*" shall be observed to ensure adequate system reliability performance while supplying the load.

The interconnection shall not degrade the safe operation, integrity and reliability of the BC Hydro System. These interconnection requirements are intended to protect the Transmission System but cannot be relied upon to protect the PGF. The GO is responsible for protecting their own system. This document provides information on the interconnection requirements for use by GOs that have an interest in interconnecting to the Transmission System and identifies:

- The minimum technical requirements the GO's equipment shall meet if connecting to the Transmission System at or above 60kV, and
- The expected system conditions their facilities will encounter when connected to the Transmission System.

These requirements will ensure that the GO's equipment will:

- At all times be compatible with the safe operation of the Transmission System;
- Maintain a high standard of quality and reliability of electricity supply;
- Meet BC Hydro's applicable operating, dispatching, metering and protection requirements; and
- Meet the requirements of regulatory agencies and authorities such as the BCUC and where applicable NERC and WECC.

The GO owns and is responsible for the design, installation, operation, and maintenance of all necessary equipment, station and transmission line facilities that are required to connect its facilities to the Transmission System, unless otherwise agreed to in writing. The GO is responsible for obtaining all regulatory approvals, including environmental assessment approvals, if necessary, for the construction and operation of its facilities.

4. Required Technical Data from Generator Owners

BC Hydro requires different detail levels of generating facilities data throughout various stages of the life of a generator interconnection project or facility. The prospective or existing GOs are required to submit the generating facility data typically in three stages, which are the primary components of the interconnection process (including Interconnection Feasibility Study, Interconnection System Impact Study, and Interconnection Facilities Study, each as defined in the OATT), the interconnection commissioning stage, and the Commercial Operation stage. Specific submission requirements at each stage are described below. The typical generating facility data requirements are also listed in Appendix B of this document and additional information for supervisory control ad data acquisition (SCADA) is stated in Section 9.5.

Interconnection Study Stage

The GO of a PGF facility is required to submit a Generator Interconnection Data Form (GIDF) for a new interconnection or Materially Modified Interconnection, which is applicable to all types of generating facilities including all synchronous generators, all IBR generating facilities, and other asynchronous generators. There are two versions of the GIDF form; one for Feasibility Studies, and one for System Impact Studies. The GIDF is available on the BC Hydro website:

> https://app.bchydro.com/accounts-billing/electrical-connections/transmission-generator-interconnections.html

The GIDF, one of the supporting documents to complete an Interconnection Request (**IR**), includes the information of facility location, POI, generating capacity to be installed, station single line diagrams, the collector system if applicable, schematic diagrams of protection and control, step-up transformer and main power transformers, circuit breakers, electrical parameters, and modeling information of generating facilities etc. The generator modeling info will need to be submitted in software platforms and versions that are acceptable to BC Hydro. BC Hydro uses PSSE, PSCAD and ASPEN software in its transmission planning and fault analysis work.

The owner of a BES generator is required to register with the BCUC through their administrator WECC. Depending on the type and size of the generator, the aggregate power injection at the POI, the voltage class of the transmission interconnection, and other criteria as defined by NERC and adopted by the BCUC, the requirements of the BC Mandatory Reliability Program may apply. It is the GO's responsibility to ensure compliance with the program requirements.[2]

The GO shall provide complete models for each component of the PGF. The GO shall also provide fault level table of IBR(s) as part of customer submitted GIDF. Table containing IBR current and angle at various voltage points must be included. The IBR manufacturer should be able to provide the requested IBR fault data table for further detailed studies. The proponent may be requested to provide new IBR models to BC Hydro per the most up to date industrial

[2] For more information, please refer to the NERC *Bulk Electric System Definition Reference Document.*

standards for evaluation or better understanding of PGF response to system disturbances even after the PGF is in service. BC Hydro may add new requirements as it receives more updated or detailed IBR models from the proponent. The models and their associated data shall be validated in accordance with Appendix B – Data Requirements.

The model must provide an accurate representation of the behaviour of the generation equipment and related power equipment during and after a disturbance, including the effect of control and protection systems on the response of the equipment or wind farm.

The information in the submitted GIDF is the GO's inputs used in the interconnection studies that BC Hydro performs for the facility interconnection. Changes to the GO's inputs could result in invalidity of the interconnection studies that BC Hydro performed. It is not uncommon that certain changes to the submitted information occur during the project development stage. When such changes occur, the GO is obligated to inform BC Hydro, in a timely manner, of the changes for acceptance and approval by BC Hydro if the changes will not cause a problem. In some cases, the changes may be determined by BC Hydro to be so material that the interconnection studies will need to be re-done upon receipt of the updated information from the GO.

If the GO does not provide a timely update to BC Hydro of the changes to the submitted GIDF, the interconnection studies that BC Hydro completed may become invalid, and so may the signed interconnection agreements, which can be grounds for delaying the interconnection process including delaying commercial operation of the PGF.

Commissioning Stage

To support preparation of the interconnection commissioning and the coordination work during the commissioning period, the GO is required to submit the updated information in GIDF to BC Hydro reasonably early enough prior to the Trial Operation (as defined in the OATT). Information in this submission shall be the most current generating facility installation/design or expected performance data including the update to the modelling information used in the interconnection studies. The information update will also be used in operation preparations including the power system stabilizer (**PSS**) settings if required, and creation of Transmission System Operating Orders (as defined in the OATT) or update to the existing Transmission System Operating Orders after the generating facility to be in service.

If the updated data at this stage is materially different from what was provided for the completed interconnection studies, then BC Hydro will conduct appropriate studies to determine the impact on the Transmission System based on the updated data received. The GO will carry a potential risk for possible additional requirements imposed on the project, which could negatively affect the facility commissioning work and commercial operation date.

Commercial Operation Stage

Subsequent to the Commercial Operation Date, the GOs are required to notify and provide BC Hydro details of any proposed material modifications to the interconnected facilities due to equipment replacement, repair, adjustment, or upgrade.

The GOs are also required to submit the generator modeling verification information periodically to BC Hydro per the requirements of the BC Mandatory Reliability Program. The relevant BCMRS include, but not limited to: FAC-008, MOD-025, MOD-026, MOD-027, MOD-032, PRC-019, PRC-024. It is the GO's responsibility to ensure compliance with the program requirements, including all applicable standards and periodic updates as new standards are adopted for use in BC.

For the generating facilities that are not subject to the MRS compliance requirements, BC Hydro generally adopts the technical requirements from NERC and WECC but the resubmission cycles may be longer than the required by NERC/WECC.

5. General Requirements

The interconnection of GO's equipment shall comply with codes, standards, and criteria applicable in BC, and with Good Utility Practice.

Construction of the PGF shall be performed in an environmentally responsible and safe manner in accordance with applicable Federal and Provincial regulations and standards.

The GO shall notify BC Hydro prior to any alterations to its connected facilities, both during the design stage and after the PGF commences commercial operation. Changes that affect the PGF's performance including station configuration, equipment rating, fault contribution, generator performance, control, protection schemes and protection settings require BC Hydro's prior approval.

EHV requirements will be determined on a case-by-case basis; the additional requirements for the PGF could include but not limited to the following aspects, high-speed clearing and reclosing, Level 1[3] communications system, and insulation coordination to ensure comparable performance to the Main Transmission System.

5.1 Limitations of Minimum Size Synchronous Generator

Conventional synchronous generators are subject to generator self excitation if loaded with a capacitive load greater than 80% of the MVA rating of the machine, assuming a typical synchronous reactance. As unloaded transmission lines, in an islanding condition, are a capacitive load, generator self excitation could occur if the connected generator is too small to absorb the VARs from the transmission lines. PGFs when connected to the Transmission System should meet the criterion that:

0.7 times On-Line Generation MVA > Open-ended Line Charging MVA

[3] Level of communication system is referring to percentage of availability and is defined in WECC "Communications Systems Performance Guide for Protective Relaying Applications".

(Units with higher synchronous reactance will have to be proportionately larger.)

If this principle is not met, costly mitigations will be required.

5.2 Safety and Isolating Devices

At the POI, an isolating disconnect device shall be installed and shall meet the following requirements:

(a) It physically and visibly isolates the Transmission System from the PGF.

(b) It complies with safety and operating procedures of WorkSafeBC.

(c) It is rated for the voltage and current requirements of the application.

(d) It is gang operated.

(e) It is operable under all weather conditions in the area.

(f) It is lockable in both the open and closed positions.

(g) It is accessible to BC Hydro at all times.

(h) Its control and operation are governed by the operating agreements between the GO and BC Hydro (normally in the form of “Local Operating Orders” (**LOOs**)).

The disconnect device is provided for isolation and cannot normally be used to interrupt load current or significant line charging current. Its location, capacity and operating rules must be carefully established and documented.

The isolation device may be placed in a location other than the POI by agreement of BC Hydro and affected parties.

BC Hydro personnel may lock the isolating device in the open position and install safety grounds:

(a) For the protection of maintenance personnel when working on de-energized circuits;

(b) If the connected facilities or BC Hydro equipment presents a hazardous condition; or

(c) If the connected facilities jeopardize the operation of the BC Hydro System.

5.3 Point of Interconnection Requirements

5.3.1 General Constraints

The connection methods described below are examples of possible connection methods only. They are not intended to be a guide to the GO as to which connection method is appropriate to the application. The connection method is site and system dependent. As well, the telecommunication structure available (or lack thereof) is a key factor. Thus, BC Hydro will make the determination of connection method for each application at the time of interconnection studies.

The connected facilities shall not restrain BC Hydro from taking a transmission line, line section or other equipment out of service for operation and maintenance purposes. The interconnection line and all its components shall be designed and installed to be maintainable within BC Hydro's maintenance requirements.

The PGF shall be designed for operation at short circuit (fault) levels that consider future development of the BC Hydro System. The short circuit levels to be used in the design depend on the POI and future planned development and are available on request.

5.3.2 General Configurations

Connection of new generation facilities into the Transmission System generally falls into one of three categories:

1. Connection into an existing 60 kV to 500 kV substation with (depending on the bus configuration) the existing transmission, and new connecting lines each terminated into bays containing one or more breakers.
2. Connection by looping an existing 60 kV to 500 kV transmission line into a new BC Hydro substation provided to terminate a new line from the GO.
3. Connection into an existing 60 kV to 230 kV transmission line via a tap. Acceptability of a line tap proposal is to be determined by BC Hydro. Whether a tap is acceptable or not will depend on BC Hydro's assessment of the system and reliability risks, with priority given to ensuring the reliability of the existing BC Hydro System and customers. BC Hydro reserves the right to reject proposals for line taps and require the termination of a generator interconnection at a substation.

Where a GO proposes to interconnect and deliver power to BC Hydro via a third party private transmission line, in addition to BC Hydro's Transmission Interconnection Requirements for Power Generators, the third party owner(s) of that private transmission line must agree with the GO proposal. The GO must notify the private owner(s) of the line of their responsibility to assess the impact of the GO interconnection to their private facilities. BC Hydro will require a copy of the agreement between the GO and the third party transmission line owner. Additional regulatory requirements may apply (see Section 11).

BC Hydro must maintain full operational control of the transmission interconnection path, which includes, but not limited to, SCADA control and monitoring of circuit breakers, disconnects and other equipment in the new substation. Any new equipment shall not degrade the operational capability of the line.

Safety and security rules are in place to prevent un-authorized personnel from having physical access to BC Hydro stations. Design consideration, particularly for protection and control, must include these rules.

Figures below show the different connections using synchronous generator resources as examples. Same principles also apply to connections of non-synchronous resources.

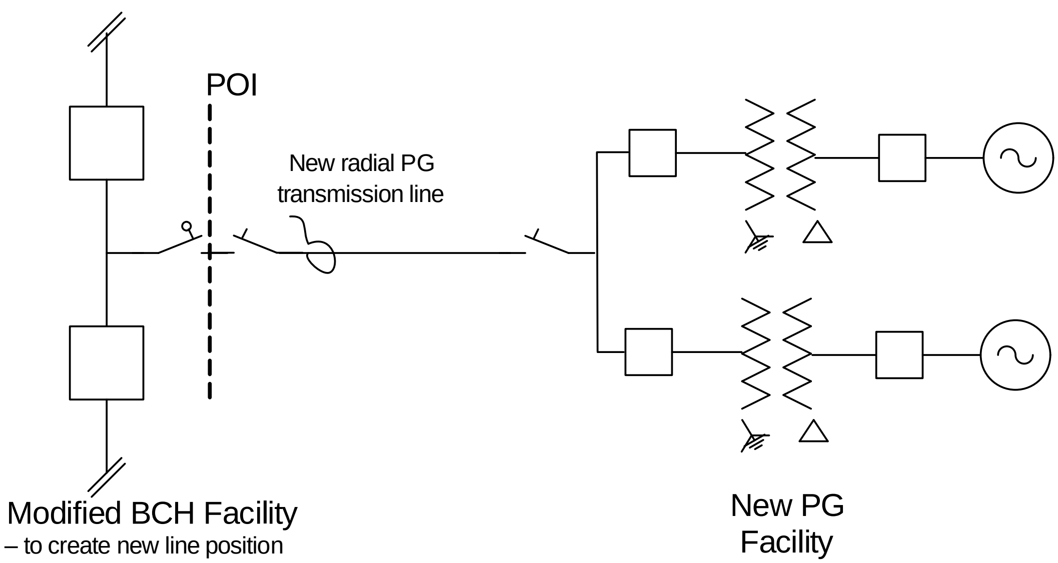
The following Figure 1 illustrates Case (a). The pertinent points to this form of interconnection are:

A dedicated line built, owned, and operated by the GO is brought into an existing BC Hydro facility.

The BC Hydro facility has been modified to accommodate a new line position. For example, if the existing BC Hydro bus arrangement is a ring bus, a new breaker is required to be installed in the ring to establish a new line position for the new radial line.

Note: In addition to the Motor Operated Disconnect Switch (**MODS**) at the BC Hydro station, a ganged disconnect is provided immediately on the GO side of the POI. This allows either party (BC Hydro or GO) to isolate the line without physical access to the other party's facility.

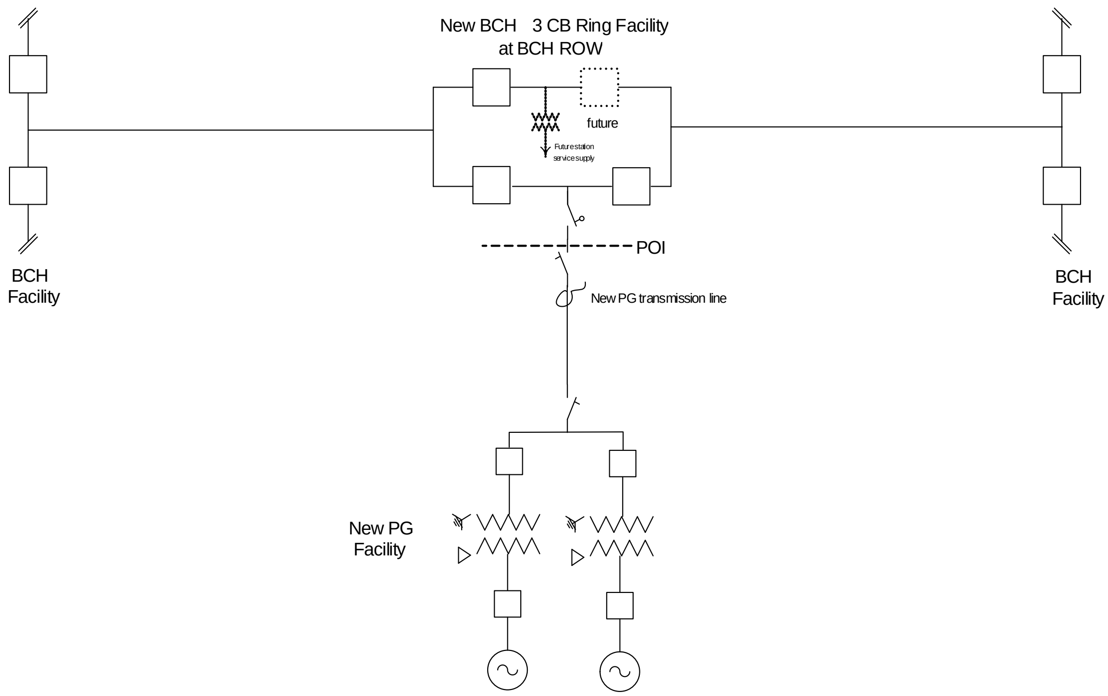
Figure 1: Case (a) – Connecting into existing 60 kV to 500 kV BC Hydro Bulk Station



Note: Although a Synchronous generator is shown in the diagram it is meant to represent both Synchronous and IBR generators.

The starting point for the evaluation of connection is a new radial line to existing or new BC Hydro facilities as shown in Figure 2. Modifications from this approach (such as the other examples that follow) will be determined on a case-by-case basis. Figure 2 Case (b1) illustrates a safe, reliable, and flexible configuration where BC Hydro provides a switching station at the transmission right-of-way (ROW), adjacent to the line.

Figure 2: Case (b1) - New BC Hydro Station Connecting Into Existing Transmission Line at ROW



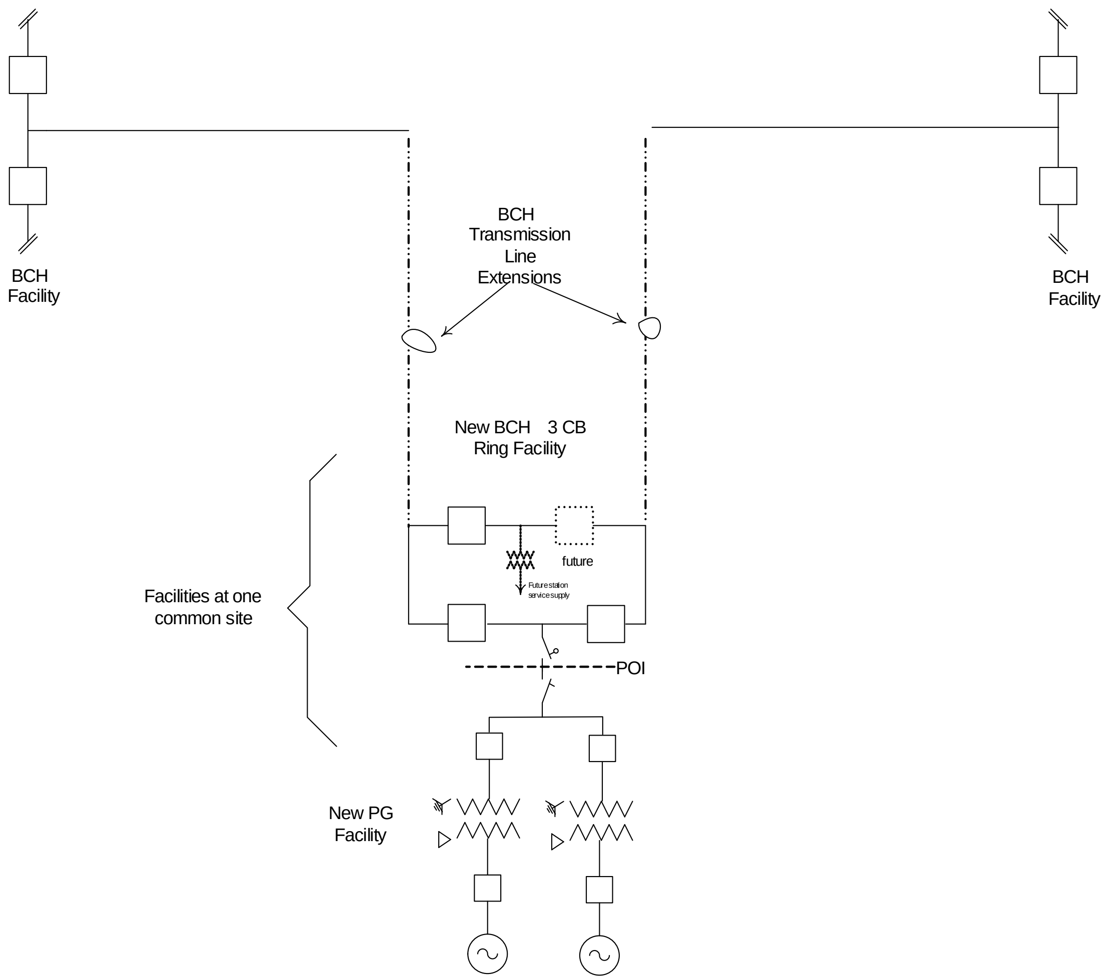
Note: Although a Synchronous generator is shown in the diagram it is meant to represent both Synchronous and IBR generators.

Case (b2), Figure 3 below, is a variant of Case (b1) where it is not practical to build a new station immediately adjacent to the existing transmission line right-of-way. As shown, BC

Hydro transmission line extensions are brought to a new three breaker ring station near the PGF. The pertinent points to this form of interconnection are:

- A short section of dedicated line or bus work built and owned by the GO is brought into a new BC Hydro three breaker ring facility.
- The BC Hydro facility is usually located physically adjacent to the PGF.

Figure 3: Case (b2) - New BC Hydro Station Connecting near PGF



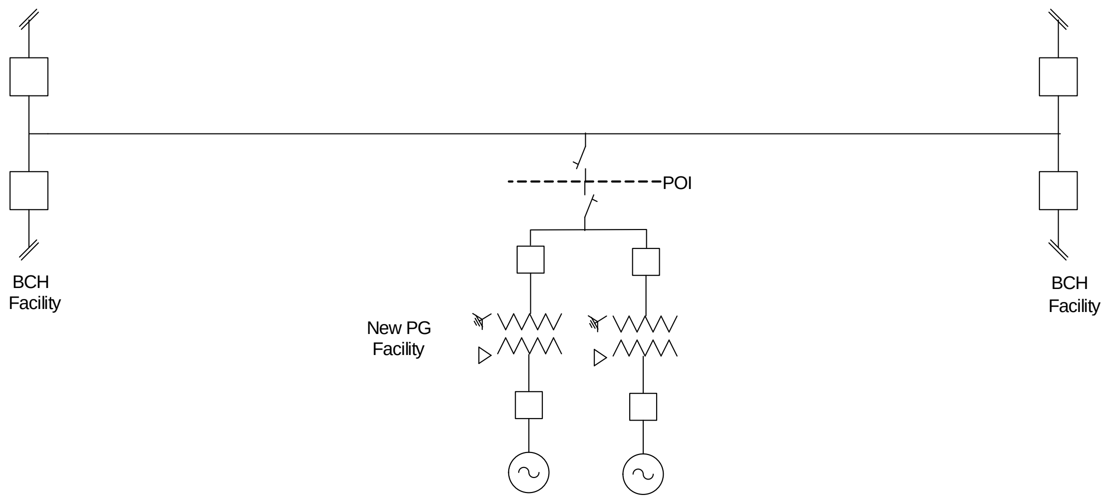
Note: Although a Synchronous generator is shown in the diagram it is meant to represent both Synchronous and IBR generators.

Case (c) is shown in Figure 4 below. Generally, this installation is not desirable because of its negative impact on transmission protection and security.

If it is to be considered, three-terminal line current differential protection may resolve the protection issues. However, it will require a substantive (broadband) telecommunications infrastructure. Furthermore, such an installation may not be possible if there are existing taps or taps planned for the transmission line.

Note that a line with three terminals affects BC Hydro's ability to protect, operate, dispatch, and maintain the transmission line. BC Hydro determines the permissibility of multi-terminal line connections on a case-by-case basis. BC Hydro will define specific protection requirements for the PGF terminal of a multi-terminal line in those few cases where they can be permitted.

Figure 4: Case (c) - PGF Tapped to BC Hydro Transmission Line



Note: Although a Synchronous generator is shown in the diagram it is meant to represent both Synchronous and IBR generators.

5.3.3 Special Configurations for 500kV

The BC Hydro 500kV Bulk Transmission System is the backbone of the British Columbia transmission system and provides the primary means of serving large geographical areas. Line taps to the 500kV system will not be considered. If a 500kV connection is permitted, BC Hydro will construct a substation with sufficient redundancy in accordance with Good Utility Practice to maintain reliability and security of the main grid system. Selection of an alternative POI is encouraged.

5.3.4 BC Hydro Rights of Way and Properties

Location of GO interconnection facilities on or adjacent to BC Hydro Rights of Way or BC Hydro fee-owned properties shall require a BC Hydro Properties Referral, and additional requirements shall be determined specific to the design of the facilities being proposed and the subject locations. This is generally coordinated during the Facilities Study stage.

5.4 Transformer Considerations

5.4.1 New Installations

Transformers connecting to the Transmission System where a source of real power flows through the transformer to the BC Hydro high voltage Transmission System shall provide a source of ground current on the high voltage side. It is also required to separate the high voltage side zero sequence from the GO side A YG-Δ or a YG- Δ -YG transformer with the Y-ground connection on the high voltage side can accomplish this. A YG-YG connection is only appropriate if there is a sufficient ground source on the low voltage side and will need to be evaluated by BC Hydro before being permitted. Auto-transformers with delta connected tertiary windings are acceptable for connecting lower voltage collector networks.

5.4.2 Existing Installations

GO added to existing load sites served by Δ-YG transformers may require transformer replacement or additional equipment, such as a grounding bank, to avoid ungrounded system operation. If the Δ-YG is permitted to be retained, relay protection schemes may also be required to ensure immediate disconnection of the power source following a disconnection of the Transmission System. BC Hydro will consider these on a case by case basis.

5.5 Other Interconnection Considerations

5.5.1 Existing Equipment

The interconnection study may show that the proposed new connection may cause existing system equipment such as transformers, power circuit breakers, disconnect switches, arresters, and transmission lines to exceed their ratings. Exceedance of ratings is not permitted under the NERC Transmission System Planning Performance requirements, and so the interconnection studies will identify where replacement of the impacted equipment or development of alternate plans of service is necessary.

5.5.2 System Stability and Reliability

The BC Hydro System has been developed with careful consideration for system stability and reliability during disturbances. The type of connection, size of the source or load, breaker configurations, source or load characteristics, and the ability to set protective relays will affect where and how the connection is made. The GO should expect to be required to participate in special protection or RAS including automatic generation tripping and load shedding.

5.5.3 Protection and Control

BC Hydro coordinates its protective relays and control schemes to provide for equipment protection and to minimize disruption of services during disturbances. New connections usually require addition or modification of protective relays and/or control schemes, including replacement or modification of equipment at the remote terminal(s). The new protection shall be compatible with existing protective relay schemes and present standards. The addition of voltage transformers, current transformers, or pilot scheme (transfer trip) may also be necessary. BC Hydro will recommend or specify, as appropriate, protective relay systems to protect BC Hydro assets.

Should the GO select a relay system different from BC Hydro applications for other parts of the PGF, BC Hydro reserves the right to perform a full set of acceptance tests prior to granting permission to use the selected protection scheme. GO selected equipment shall have interfaces compatible with BC Hydro equipment.

BC Hydro will assess whether communication assisted line protection is required on a case by case basis.

5.5.4 Revenue Metering

Revenue metering shall be discussed and included in the interconnections process before the design phase. The location of the point of metering shall be in accordance with BCH Complex Metering Requirements and, approved by BCH Revenue Metering Department during the design stage.

The required meters at the point of metering shall be installed and commissioned prior to connecting the customer's installation to the Transmission System.

The revenue metering shall be in accordance with Measurement Canada federal regulations and, in accordance with, BC Hydro's Requirements for Complex Metering, which is available at:

> https://app.bchydro.com/accounts-billing/electrical-connections/distribution-standards/LA-RM-Complex-RM.html

5.5.5 Dispatching for System Operations and Maintenance

BC Hydro operates and maintains its system to provide reliable customer service while meeting the seasonal and daily peak loads even during equipment outages and disturbances. New line and generation connections shall not restrict timely outage coordination, automatic switching, or equipment maintenance scheduling. Preserving reliable service to all BC Hydro customers is essential and may require additional switchgear, equipment redundancy, or bypass capabilities at the POI for acceptable operation of the system.

5.5.6 Atmospheric and Seismic

The effects of windstorms, floods, lightning, elevation, temperature extremes, icing, forest fire, contamination, and earthquakes must be considered in the design and operation of the connected facilities. The GO is responsible for determining that the appropriate standards, codes, criteria, recommended practices, guides, and Good Utility Practice are met for equipment that they are installing.

5.5.7 Physical Security

The potential vulnerability of the facility to sabotage or terrorist threat should be factored into the design and operating procedures. The GO is responsible for determining that the appropriate standards, codes, criteria, recommended practices, guides and Good Utility Practice are met for equipment that they are installing.

5.6 Transmission and Substation Facilities

Some new connections to the BC Hydro System may require that one or more BC Hydro lines (a transmission path) be looped to a new BCH substation for connection to the GO's facilities or sectionalized with the addition of switches. The design and ratings of these facilities shall not restrict the capability of the line(s) and BC Hydro's contractual transmission path rights.

5.7 Insulation Coordination

Power system equipment is designed to withstand voltage stresses associated with expected operation. Adding or connecting new facilities can change equipment duty and may require existing equipment be replaced or new switchgear, telecommunications, shielding, grounding and/or surge protection be added to control voltage stress to acceptable levels. Interconnection studies shall include the evaluation of the impact on equipment insulation coordination. BC Hydro may identify additional requirements to maintain an acceptable level of BC Hydro System availability, reliability, equipment insulation margins and safety.

Voltage stresses, such as lightning or switching surges, and temporary over-voltages may affect equipment duty. Remedies depend on the equipment capability and the type and magnitude of the stress. In general, stations with equipment operated at 15 kV and above, as well as all transformers and reactors, shall be protected against lightning and switching surges. Typically, this includes station shielding against direct lightning strikes, surge arresters on all transformers, reactors, and surge protection with arresters on the incoming lines.

When new equipment is connected to the BC Hydro network, they shall not degrade existing BC Hydro System operating performances and capabilities. Generally, to avoid potential problems, components for the new system shall have lightning, switching and temporary over-voltage performances that are comparable to the existing BC Hydro System.

Each substation shall have a ground grid that is solidly connected to all metallic structures and other non-energized metallic equipment. This grid shall limit the ground potential gradients to such voltage and current levels that will not endanger the safety of people, or damage equipment, which are in or immediately adjacent to the station under normal and fault conditions. The ground grid size and type are in part based on local soil conditions and available electrical fault current magnitudes. In areas where ground grid voltage rises beyond acceptable, safe limits (for example due to high soil resistivity or limited substation space), grounding rods and grounding wells might be used to lower the ground grid resistance to limit station ground potential rise to below 5 kV.

BC Hydro lines are typically not shielded from lightning, and the tower footing resistances can be much larger than those normally encountered for shielded lines. For security reasons, most lines have a (10s) reclose feature while EHV lines have possibility for high-speed (0.5 - 1.0s) reclose. Also, some lines on the BC Hydro System are insulated for future use at a higher system voltage than present operation. For example, a 230 kV line may be built to 500 kV standards. Connections to these lines shall be designed and insulated with the ultimate usage taken into account. Some equipment in the station such as transformers, surge arresters and circuit breakers may be rated for the actual operating voltage, but special attention shall be given to insulation coordination in consideration of the higher surges that the line can deliver to the station.

All BC Hydro stations are fully shielded while line shielding over short distances from the station are applied on lines operated at 230 kV and above. Surge arresters are applied at the line terminals to limit incoming lightning and/or switching over-voltage surges.

5.7.1 Lightning Surges

If the GO proposes to tap a shielded transmission line, the tap line to the PGF substation shall also be shielded. For an unshielded transmission line, the tap line does not typically require shielding beyond what is needed for substation entrance. However, special circumstances such as the length of the tap line may affect shielding requirements.

All lines that terminate at BC Hydro substations must have station entrance surge protection while those at 230 kV and higher require short lengths of shielding from station with compatible tower footing resistances. (See section 6.3.2 Table 4 for line shielding requirements of lines entering BC Hydro stations.)

Where the GO interconnection facilities (transmission lines) are located in proximity to existing BC Hydro transmission lines, additional coordination of line design, anchor locations, and grounding may be required to reduce the likelihood of simultaneous outages caused by lightning.

5.7.2 Switching Surges

Lines and stations require attention to switching surge voltages in their design. BC Hydro will provide information on the specifics of switching surge voltage for particular locations on request.

5.7.3 Temporary Over-voltages

Temporary over-voltages can last from seconds to minutes and are not characterized as surges. These over-voltages are present during Islanding, faults, loss of load, or long-line situations. All new and existing equipment shall be capable of withstanding these duties.

The standard system voltages are as shown in the Table 1 below.

Table 1: System Voltages

Voltage Class (kV RMS, L-L)	**Normal Maximum Voltages** (kV RMS, L-L)
69	72.5
138	152
230	253
287	315
345	380
500	550

5.7.4 Neutral Shifts

When generation is connected to the low-voltage, grounded wye side of a delta-grounded wye (Δ–YG) transformer as may occur due to the addition of on-site generation to an existing load, opening the remote line terminal connection due to unbalanced fault clearing may cause over-voltages on the high-voltage terminal. These over-voltages can affect personnel safety and damage equipment. This type of over-voltage is commonly described as a neutral shift and can increase the voltage on the un-faulted phases to 1.73 per unit or higher if there is significant line capacitance. At this voltage, the equipment insulation withstand duration can be very short. Several alternative remedies to avoid neutral shift and its potential problems are possible. The following describes three possible solutions acceptable to BC Hydro.

a) Effectively Grounded System

An effectively grounded system is defined as a system with $X_0/X_1 \leq 3.0$ and $R_0/X_1 \leq 1.0$. An effectively grounded system will minimize the risk of damage to surge arresters and other connected equipment. Utilizing appropriate transformer connections on the high-voltage side will make the system effectively grounded. Transformer connections typically used to obtain an effective ground on the high-voltage side of a transformer include the following:

1. A transformer with the transmission voltage (BC Hydro) side connected in a YG configuration and low-voltage side in a closed Δ.

   A HV YG – LV Delta is required so that the step-up transformer is an effective source of zero sequence current on the HV side to ensure that effective grounding of the HV grid is maintained. It is also required to separate the HV grid zero sequence from the MV grid zero sequence for protective relay ground coordination purposes.

2. A three winding transformer with a closed Δ tertiary winding and both the primary and secondary sides connected YG.
3. Installation of a grounding transformer on the high-voltage side.

   Typically, WGF will have a medium voltage (**MV**) collector network and need a ground source on the MV side of the step-up transformer. The recommended HV grounded wye-LV Delta transformer does not provide the desired MV ground so a grounding transformer is recommended on the MV side in conjunction with a HV YG-LV Delta transformer.

b) Increase Insulation Levels

Rate the insulation of equipment connected to the transmission line high-voltage side to be able to withstand the expected amplitude and duration of the neutral shift. Switchgear that interrupts faults or load supplied from a Δ connected transformer winding shall be capable of withstanding increased recovery voltages. Increased insulation would also need to be applied at the remote line terminals and any stations tapped to the line.

c) High Speed Separation

Rapidly separate the back-feed source from the step-up transformer by tripping a breaker using either remote relay detection with pilot scheme (transfer trip) or local relay detection of the over-voltage condition. In general, it is not acceptable to disconnect the PGF after the line terminals have already opened due to considerations of surge arrester thermal and equipment insulation withstand capability.

5.8 Substation Grounding

Each substation shall have a ground grid that is solidly connected to all metallic structures and other non-energized metallic equipment. This grid shall limit the ground potential gradients to such voltage and current levels that will not endanger the safety of people, or damage equipment, which are in or immediately adjacent to the station under normal and fault conditions. The ground grid size and type are in part based on local soil conditions and available electrical fault current magnitudes. In areas where ground grid potential rises beyond acceptable, safe limits (for example due to high soil resistivity or limited substation space), grounding rods, grounding wells and remote grounding grid might be used to reduce the ground grid resistance to acceptable levels.

If a new ground grid is close to another substation, the two ground grids may be isolated or connected. If the ground grids are to be isolated, there shall be no metallic ground connections between the two substation ground grids. Cable shields, cable sheaths, station service ground sheaths and overhead transmission shield wires can all inadvertently connect ground grids. Fibre-optic cables are highly preferable for providing telecommunications and control between two substations while maintaining isolated ground grids. If the ground grids are to be interconnected, the interconnecting cables shall have sufficient capacity to handle fault currents and control ground grid voltage rises. Any connection to a BC Hydro substation ground grid must be approved by BC Hydro.

New interconnections of transmission lines and/or generation may substantially increase fault current levels at nearby substations. Modifications to the ground grids of existing substations may be necessary to keep grid voltage rises within safe levels. The interconnection studies will determine if modifications are required.

The ground grid should be designed to applicable CSA, and IEEE Standards relating to safety in substation grounding.

5.9 Inspection, Test, Calibration and Maintenance

Transmission elements (e.g. lines, line rights of way, transformers, circuit breakers, control and protection equipment, metering, and telecommunications) that are part of the proposed connection and could affect the reliability of the BC Hydro System need to be inspected and maintained in conformance with regional standards and Good Utility Practice, including vegetation management. The GO has full responsibility for the inspection, testing, calibration, and maintenance of their equipment, up to the location of change of ownership or POI as applicable. BC Hydro may also have additional maintenance requirements for owners of tapped connections, to ensure the Transmission Maintenance and Inspection Plan (**TMIP**) requirements are a portion of the WECC Reliability Management System for Transmission.

The GO or utility may be required by WECC to annually certify that it has developed, documented, and implemented an adequate TMIP.

5.9.1 Pre-energization Inspection and Testing

The GO is responsible for the pre-energization and testing of their equipment.

For equipment that can impact the BC Hydro System, the GO shall develop an inspection and test plan for pre-energization and energization testing. BC Hydro may request to review the test plan prior to the test(s). BC Hydro may require additional tests. The GO shall make available to BC Hydro, upon request, all drawings, specifications, and test records of the POI equipment. Also, upon request, BC Hydro will make available to the GO similar documents describing the BC Hydro POI equipment.

5.10 Station Service

Power that is provided for local use at a substation to operate lighting, heating and auxiliary equipment is termed station service. Alternate station service is a backup source of power, used only in emergency situations or during maintenance when primary station service is not available.

Station service power is the responsibility of the GO. The station service requirements of the new facilities, including voltage and reactive requirements shall not impose operating restrictions on the BC Hydro System.

Appropriate providers of station service and alternate station service are determined during the interconnection study and planning process, including project requirements diagram development and review.

5.11 Back-up Power

Back-up power is deemed to be the supply of power from the Transmission System to energize the PGF thus allowing the PGF to recover from a total shut-down. It is up to the PGF proponent, and their engineer, to make arrangements for back-up power supply with an electric power service provider.

5.12 Black Start Capability

Black start capability is the GO's capability to self start its generation plant in isolation from the Transmission System and to pick up part of the BC Hydro System under islanding conditions. If Black start capability is needed, BC Hydro will advise the GO at the time of interconnection studies.

A black start plant in the BC Hydro System is typically a hydro generating plant with sizable reservoir. A BESS IBR with adequate stored energy may have potential to offer black start capability where a novel technology of "Grid Forming" is used in such an application, special studies will need to confirm its ability for the intended purpose.

If the PGF is not equipped with the self start capability, the GO shall take appropriate design measures to ensure that the PGF can be energized from the BC Hydro System without causing unacceptable performance to BC Hydro System and the PGF. In particular, the PGF shall ensure that energization of the interconnection transformer to the BC Hydro System will not result in voltage sags at the POI that exceed the limits specified in section 6.2.3 Table 2. Please consult the IEEE technical paper "Assessing and Limiting Impact of Transformer Inrush Current on Power Quality", IEEE Transactions on Power Delivery, Vol. 21, No.2, April 2006.WGF proponent shall provide a means to facilitate the disconnection of the WGF by BC Hydro and to also prevent reconnection in the event of black start. It shall be possible for BC Hydro to send a trip and inhibit signal to the circuit breaker(s) at the WGF POI. A WGF may only be reconnected (i.e., made live) when the network is fully restored following instructions to reconnect from BC Hydro. If BC Hydro deems it acceptable to do so on rare occasions, the WGF may be instructed to reconnect prior to full grid restoration to assist with such purpose.

5.13 Synchronizing Facilities

Automatic synchronizing relays typically contain frequency, voltage, slip and phase angle matching elements, and breaker close compensation. These elements shall be set to assure orderly synchronization to the BC Hydro System. If there is a possibility of the two systems being tied together where a parallel path already exists, then the scheme shall be augmented with a synchro-check relay.

All automatic synchronization shall be supervised by a synchronizing check relay, IEEE device 25. This is to ensure that the generator is not connected to the energized power system out of synchronization. It is preferred to use two independent sources of voltage transformer (**VT**) connections to the automatic synchronizer and synchro check relay.

5.14 Certification of the Power Generating Facility

A Professional Engineer, registered in the Province of British Columbia, must declare that the PGF has been designed, constructed, and tested in accordance with:

- The interconnection requirements stated in this document,
- The project specific requirements as stated by BC Hydro,
- Good Utility Practice, and
- Applicable standards.

All reports, drawings, equipment specification and modelling data of technical nature (excluding manufacturing drawings) shall be stamped by a Professional Engineer registered in the Province of British Columbia.

6. Performance Requirements

The following performance requirements can be satisfied by various methods. It is the responsibility of the GO to provide the appropriate documentation and/or test reports to demonstrate compliance.

6.1 Electrical Disturbances Requirement

The PGF shall be designed, constructed, operated, and maintained to meet the requirements specified in this document, all applicable laws, regulations, reliability requirements and standards with respect to the following characteristics:

- Electric system disturbances that produce abnormal power flows,
- Over-voltages and under-voltage,
- Over-frequency and under-frequency,
- Resonance,
- Power system faults and equipment failures,
- Audible noise, radio, television and telephone interference,
- Power system harmonics, and
- Other disturbances that might degrade the reliability of the interconnected BC Hydro System.

6.2 Power Quality

6.2.1 Self Excitation and Resonance Phenomena

The GO shall assess the risk of self-excitation of machines and implement appropriate design measures to protect the PGF as required. Unbalanced faults on the Transmission System shall be included in the risk considerations.

The GO shall work in consultation with BC Hydro to evaluate potential operating conditions and determine an appropriate solution. BC Hydro will provide the GO with harmonic impedance characteristics at the POI on request.

The GO shall ensure that any issues related to resonance and self-excitation are addressed in the PGF design stage.

6.2.2 Power Parameter Information System

BC Hydro requires that a Power Parameter Information System (**PPIS**) be installed at the PGF to ensure proper power quality is maintained for on-line, off-line, steady and dynamic states. The PPIS is capable of high-speed sampling to capture information such as harmonics, and voltage and current levels. The information captured will allow BC Hydro and GO staff to assess the condition of electricity generating from the PGF.

BC Hydro will provide the system's requirements, including approved measurement devices, to the GO. The GO will supply, install, and commission the PPIS at the GO's expense.

See Appendix A – Power Parameter Information System for details.

6.2.3 Voltage Fluctuations

Voltage fluctuations can result in temporary reductions or increases in the voltage magnitude at any given point within the power system.

BC Hydro defines a change threshold at 10% of normal operating voltage. Fluctuations exceeding this threshold are characterized as either sags or swells. No voltage sags or swells shall be allowed to occur that arise from the normal operation of customer equipment.

Rapid voltage changes refer to voltage fluctuations having magnitudes below the sag/swell threshold of ±10%. These changes are measured as fundamental frequency r.m.s. voltages over several cycles. Rapid voltage changes are often caused by start-ups, inrush currents or switching operation of equipment.

BC Hydro Target - Rapid voltage change limits have been adapted at BC Hydro from indicative values in CAN/CSA-C61000-3-7 Section 10.3 “Planning levels” (active).

The limits for acceptable rapid voltage changes at the POI are as shown in Table 2:

Table 2: Rapid Voltage Change Planning Limits

Number of changes n	$\Delta U/U_N$ %
2 < n ≤ 10 per hour	2.5
n ≤ 2 per hour and > 4 per day	3
n ≤ 4 per day	5
Non-ideal operating conditions	Pre-scheduled by BC Hydro

PGF Requirements – Emission limits for individual installations shall be defined with a coordination approach based on the impact that these emissions will have on the rapid voltage changes in the system of concern. The combined effect of all installations should not result in rapid voltage changes exceeding the planning level limits.

6.2.4 Voltage Flicker

Voltage flicker is the effect from light sources as a result of voltage fluctuations when magnitude changes occur in rapid succession. While it is true that rapid voltage changes are the root cause of flicker, planning limits are targeted for both rapid voltage changes and flicker independently.

Voltage flicker is measured according to the standard IEC 61000-4-15 (active). The international flicker meter provides two quantities to characterize the flicker severity. The short-term flicker severity index P_{st} should be calculated by IEC flicker meters over 10 minute intervals. The long-term flicker severity index P_{lt} will be derived from groups of 12 consecutive P_{st} values.

BC Hydro Target - Flicker limits have been adopted at BC Hydro from indicative planning levels in CAN/CSA-C61000-3-7 Section 4.2.1 (active).

Table 3: Voltage Flicker Planning Limits

Flicker Index	Limit
P_{st}	0.8
P_{lt}	0.6

PGF Requirements – The GO shall plan, design and construct the PGF based on BC Hydro provided normal system fault levels. Emission limits for individual equipment or a GO's total installation should be based on the effect that these emissions will have on the quality of the voltage at the POI. The requirement is to limit the flicker injection from the total of all fluctuating installations to levels that will not result in flicker levels that exceed the planning levels.

6.2.5 Voltage and Current Harmonics

BC Hydro Target - Harmonics can cause telecommunications interference and thermal heating in transformers; they can interfere and/or harm solid state equipment and excite resonant overvoltages. To protect equipment from damage, the PGF must manage and mitigate harmonics. Harmonic distortion is the ratio of the root mean square value of the harmonic to the root mean square value of the fundamental voltage or current. BC Hydro follows IEEE Standard 519 (active) with respect to harmonic voltage and current at the POI.

PGF Requirements - The PGF's equipment shall not cause voltage and current harmonics on the BC Hydro facilities to exceed the limits specified in IEEE Standard 519 (active). Single frequency and total harmonic distortion measurements may be conducted at the POI, or other locations on the BC Hydro System to determine whether the PGF's equipment is the source of excessive harmonics.

PGF's Equipment Withstand Capability – The PGF is expected to design their plant operation to accommodate harmonic distortion as described in IEEE Standard 519 (active).

6.2.6 Phase Unbalance

BC Hydro Target - Unbalanced phase voltages and currents can affect protective relay coordination and cause high neutral currents and thermal overloading of loads and motors. BC Hydro is targeting to supply a voltage at the POI with a maximum of 1.5% voltage unbalance (planning level) for systems 230 kV and above, and 2% (planning level) for systems less than 230kV. A voltage unbalance is defined as the ratio of negative sequence voltage with respect to the positive sequence voltage.

PGF Requirements - To protect the equipment of BC Hydro and third parties, the PGF's contribution to the total unbalances at the POI must not cause a voltage unbalance greater than 1% for systems 230 kV and above and greater than 1.5% for systems less than 230kV or a current unbalance greater than 5%.

6.3 Station and Switchgear

6.3.1 General

Circuit breakers, disconnect switches, and all other current carrying equipment connected to the Transmission System shall be capable of carrying normal and emergency load currents without damage. Only a circuit breaker (**CB**) will be acceptable as an interrupting device, for protection initiated tripping at PGF.

6.3.2 Station Insulation Requirements

In general, stations with equipment operated at high voltages must be protected against lightning, switching surges and temporary over-voltages. To achieve acceptable performance and minimize costs, insulation coordination studies shall be conducted.

Station lightning protection includes shielding of station equipment from direct lightning strikes and protection from incoming transient voltage surges on lines connected to the station. Typically, this includes:

- Station shielding using shield wires and/or masts,
- Short line overhead ground wire shielding for the first two spans outside the station,
- Surge arresters and surge capacitance (Capacitive Voltage Transformers) on incoming lines, and
- Dedicated surge arresters on major equipment with insulation systems that are subject to damage, such as transformers, reactors, and Gas Insulated Switchgear.

Short line shielding reduces fast front and large magnitude surges from strikes beyond the shielded section due to corona distortion of the propagated wave within the shielded section. The line terminal surge capacitance further decreases the voltage surge front and vastly improves the surge arrestor's ability to limit over-voltages.

Lines constructed for future operation as a higher system voltage merit special attention to these insulation coordination issues.

Switching transients require coordinated designs to protect station equipment from external surges coming into the station on lines and from surges created in the station itself during switching operations. Above 300 kV, some method(s) of limiting switching transients are usually required to achieve acceptable line switching performance by circuit breakers that are used to energize or reclose lines.

Temporary over-voltages (**TOV**) can occur during fault clearing or switching in the BC Hydro System due to high ground impedances during the isolation of faulted subsystems, where the neutral has shifted and by system resonance conditions. The severity of TOV is usually estimated by simulations. Station equipment, including surge arresters suitable for TOV expected during system operating conditions, must be selected. It may be necessary to constrain some operating conditions to achieve reliable and economical system design.

The transmission line lightning insulation level and line terminal station equipment insulation levels for BC Hydro voltage classes are listed in Table 4 and Table 5 below.

Table 4: BC Hydro Unshielded Transmission Line Lightning Insulation Levels

(Note: Lines are unshielded except for short lengths from station.)

Voltage Class (line to line kV)	Lightning Critical Flashover (CFO) (crest kV)	Minimum Shield wire length outside of Stations	Shielded Section Line Tower Footing R max (Low Frequency)
69	525	0	
138	860	0	
230	1265	1.0 km	10 ohms
287	1345	1.0 km	10 ohms
360	1665	1.0 km	15 ohms
500	1985	1.0 km	20 ohms

Table 5: BC Hydro Line Terminal/Station/TX Equipment Ratings (BIL and SIL)

(Note: Lines are unshielded except for short lengths from station.)

Voltage Class (line to line kV)	Terminal/Station/TX Equipment		Line/Station Surge Arrestors		Capacitance CCVT (nf minimum)
	BIL (kV)	SIL (kV)	V-rating	IEC-Class	
69	350/350/350	290/290/290	72/60	2	10
138	650/550/550	540/450/450	144/120	3	10
230	950/950/850	850/850/750	228/192	3	10
287	1050/1050/950	950/950/850	240/228	4	10
360	1300/1175/1175	1050/1050/950	300/288	4	10
500	1550/1550/1550	1175/1175/1175	396/396	5	10

6.3.3 Clearances

Energized parts shall be maintained at safe vertical and horizontal clearances that are compliant with the Canadian and British Columbia standards including WorkSafeBC's requirements.

6.3.4 Circuit Breaker Requirements:

All circuit breakers installed at the generation site, the interconnecting substation, the POI, or any other location on the Transmission System shall have:

- An interrupting rating equal to or higher than the fault duty at the specific location as determined by BC Hydro;
- An ability to meet BC Hydro's "ultimate" fault duty for the location. If the CB supplied has a lower interrupting rating, the GO assumes the responsibility for upgrading when necessary to accommodate changes to the system. The GO is responsible for contacting BC Hydro when system changes occur to ensure their equipment is suitably rated;
- A stated interrupting capability that does not rely on fault reduction schemes such as intentional time delays in clearing;
- An ability to perform all required switching duties, including but not limited to capacitive current switching (line/cable dropping in particular), load current switching, and out-of-phase opening; and

- An ability to perform all required duties without creating transient over-voltages that could damage equipment of BC Hydro or third parties.

6.3.5 Circuit Breaker Rated Interrupting Times and Fault Clearing Times

Table 6 specifies the rated interrupting times required of circuit breakers on the Transmission System. These times apply to HV entrance circuit breaker whether at the generation site and/or the POI. Expected multi-phase fault clearing times with telecommunications assisted protection are also stated in Table 6.

Table 6: Circuit Breaker Rated Interrupting Times and Multi-phase Fault Clearing Times for Telecommunications assisted Lines

Nominal Voltage Class	Rated Interrupting Time (Cycles)	Expected multi-phase Fault Clearing Times (Cycles)
287 kV – 500 kV	2	3 – 4
230 kV	3	5 – 6
115 kV – 161 kV	3	5 – 8
60 kV and below	5	7 – 11

Delayed clearing due to breaker failure can be up to 8 cycles longer than the times stated in Table 6.

6.4 Power Generating Facilities

The PGF shall comply with codes, standards and rules applicable in BC including NERC planning standards and WECC planning criteria. The generators shall be designed in accordance with all applicable standards and the following requirements.

6.4.1 Active Power Requirements of PGFs

The active power output should be limited to the lesser of the continuous ratings of the generating unit including the prime mover/source, the generator rated active power (MVA rating times rated overexcited power factor), and other elements in the generating system such as power transformers and circuit breakers.

The combined total active power outputs from individual generating units of a single plant or a HPP less its local loads shall not result in the Maximum Power Injection to the BC Hydro System exceeding the limits at the POI as proposed or permitted for the PGF's interconnection.

In addition, for a BESS plant or a BESS hybrid plant that needs to be charged from the BC Hydro System, the maximum charging load shall not exceed the limits at the POI as proposed or permitted for the PGF's interconnection. Additional interconnection requirements for load may apply to a power generator charged from the BC Hydro System.

The BESS GO shall provide the P values for the active power limits; Pmax for maximum discharging and Pmin for maximum charging which is represented with a negative P value. Note that the maximum discharging limit (**Pmax**) may be different than the absolute value of the maximum charging limit (**Pmin**). The Pmax and Pmin should be set to limits imposed by the plant and inverter controllers in coordination with the capability of the inverters.

For a BESS hybrid plant, the GO shall provide the hybrid plant total MW output limits which may be limited by the interconnection agreement, plant controller or other factors. The plant limits may be less than the individual limits of BESS and other generating resources in the plant. The GO also needs to indicate whether the BESS will be charged from the BC Hydro System or its own resources within the hybrid plant. Unless otherwise requested by BC Hydro, BESS plants / BESS hybrid plants shall not be charged from BC Hydro System. Depending on the charging sources, the total plant output will be affected accordingly.

6.4.2 Reactive Power Requirements of PGFs

Synchronous Generating Facilities

All synchronous generating units shall have the minimum capability of operating continuously in a range from an over-excited power factor of 90% to an under-excited power factor of 95% over the generating unit's complete range of output power. These power factors are specified based on measurement at the synchronous generator terminals.

Under certain transmission system conditions and voltage, based on system impact study results, the over-excited power factor of 95% is acceptable.

All synchronous generating units shall have the thermal ability to operate continuously within the confines of its reactive power capability curves, for the voltage and frequency variation range specified in IEEE C50.12-2005 Section 4.1.5. All synchronous generating units shall have the ability to follow a specified voltage schedule issued on an hourly, daily, or seasonal basis dependant upon the location of the generator. BC Hydro will either provide the generator voltage reference set point or specify desired MVAR output level for GOs to adjust the voltage set point. The generator may be required to change its voltage reference set point from time to time depending on system conditions and the location of the generator. If the BC Hydro System operator does not have direct control over the generator's voltage regulator setpoints via supervisory control, the GO's operator shall be able to implement the new MVAR output or voltage reference set point within an agreed time.

For sizable hydraulic units, it is recommended to have the direct axis synchronous reactance (**Xd**) to be less than 1.0 pu. The intent of this to enhance the power system stability in terms of pole slipping.

IBR Plants

All IBR Plants shall have the dynamic reactive power capability at a minimum of +/- 33% of its MPO from the plants at the high-voltage side of the switchyard over the full MW operating range including when BESS is in charging mode. The high voltage side of an IBR plant's switchyard is the Point of Measurement (**POM**) per NERC.

For new installations of IBR plants, each IBR unit shall be equipped with and enable the "reactive power at zero output" function in normal operations, which allows turbines or inverters to provide reactive power support at zero MW output. For example, each of the inverters in PV solar farms shall be equipped with the "reactive power at nighttime" function, and the "STATCOM mode" as named by some wind turbine manufacturers shall be used in each of the wind turbines of a wind farm.

For IBR Plants with inherent technology limitation (such as Type 3 wind - doubly fed Asynchronous generators), a partial reduction in the required dynamic MVAR capability may be permissible at or in the close proximity of zero MW output after enabling the “reactive power at zero output” function.

Some of the IBR Plants may need to install additional shunt reactive devices to meet the minimum reactive power requirements stated above. Such reactive devices include fast-acting dynamic reactive power devices such as STATCOM and SVC, and mechanically switched reactive devices such as automatically switched capacitors and switched reactors. As permitted by the BC Hydro interconnection study, the additional shunt devices may be allowed to compensate the var losses in the plant as part of the plant’s overall control system to meet the minimum dynamic reactive power capability requirements. The voltage controller shall coordinate mechanically switched shunts and dynamic reactive resources to optimize voltage regulation.

All shunt reactive devices in an IBR Plant shall be coordinated with a power plant voltage controller or similar coordinated controller, such that reactive device switching is optimized for dynamic reactive reserves to provide adequate voltage support during Transmission System disturbances.

For all IBR plants, dynamic reactive capability should be fully utilized during or following system disturbances. For example, the plant’s dynamic reactive power capability should not be artificially limited to ±0.95 power factor across the full range of active power outputs (e.g., a triangular capability curve is tailored artificially).

Other Asynchronous Generating Facilities

Other asynchronous generators include induction generators and Squirrel Cage Induction Generators (Type 1) or Wound Rotor Induction Generators (Type 2)

Induction generators and windfarms built with these wind turbines shall have the same reactive power requirement as the IBR Plants. Such windfarms shall use the appropriate ratio of automatically switched shunt reactive devices and fast acting dynamic reactive devices such as STATCOM or SVC to meet steady-state power factor and transient stability performance requirements.

6.4.3 PGF Capability Curves

GOs shall provide real and reactive power capability curves to BC Hydro.

The consolidated capability curves of the BESS hybrid plant shall be provided to BC Hydro as part of the data submission by the GO for interconnection studies. The individual capability curves of BESS and other generations in the hybrid plant shall be provided separately for modeling. The plant contractual limits that may limit the total active power to a pre-determined level should be documented and included in modeling. For preliminary study stages provisional consolidated capability curves may be acceptable.

The AC-Coupled BESS Hybrid Plant capability curve is the sum of the BESS capability curve and other generations in the hybrid plant, plus other reactive devices, and less losses within the plant as measured at the high voltage side of plant collector station transformer. The plant controller should not unnecessarily limit the plant from providing its full reactive power capability. The DC-Coupled BESS Hybrid Plants may have the total installed capacity of BESS and other resources behind the common inverter higher than the common inverter rating. In such case, the capability of DC-Coupled BESS Hybrid Plant is limited by the inverter rating.

6.4.4 Voltage Control Requirements

PGFs of all resource types shall be equipped and capable of providing automatic voltage control of POI voltages during full range of output operations.

PGFs less than 10 MVA that are connected to a relatively strong part of the BC Hydro System may be exempt from the requirement only if approved by BC Hydro.

<u>Synchronous Generating Facilities</u>

Synchronous generator excitation plays an important role in ensuring electric system stability and reliability. It shall be coordinated with generation protection to minimize generator tripping during disturbance-caused by abnormal voltage and current conditions. Excitation equipment shall comply with industry best practices and applicable industry standards for synchronous generator excitation equipment. Excitation equipment including the excitation transformer, controlled rectifier, Automatic Voltage Regulator (**AVR**), PSS and over/under-excitation limiters shall meet NERC and WECC standards, and the following requirements:

- The high initial response excitation system as defined in IEEE 421.4 standard, shall have both positive and negative ceiling voltage capability.
- The excitation system shall be able to produce the field current required for continuous operation at generator rated MVA, Rated Power Factor, 1.10 times rated terminal voltage and rated speed.
- The excitation system shall be able to provide 1.6 times the excitation system rated current at least for 30 seconds (“exciter overload current rating”).

For a synchronous generator that is larger than 30 MVA, or is part of a complex that has an aggregate capacity larger than 75 MVA:

- The excitation used shall be of the “High initial response type” as defined by IEEE Standard 421.4. The excitation shall be able to attain 95% of the difference between the available ceiling voltage and rated load field voltage in 0.1 second or less.
- The excitation ceiling voltage, defined as the maximum exciter voltage attainable under initial conditions of generator rated MVA, Rated Power Factor, rated terminal voltage and rated speed, shall be greater than 3.0 times rated field voltage (refer to IEEE Standard 421.2).unless approved in BC Hydro interconnection studies For the purpose of this requirement rated field voltage is the voltage that is required to operate the generator at rated MVA, Rated Power Factor, rated terminal voltage and rated speed.

For a synchronous generator that is 30 MVA or less, and is not part of a complex that has an aggregate capacity larger than 75 MVA,

- The excitation system nominal response as defined by IEEE Standard 421.1, shall be 2.0/s (PU / second) or higher.
- The exciter ceiling voltage shall be greater than 2 times the rated field voltage.

The GO shall provide a copy of all excitation system controls, limiters, and protective equipment settings to BC Hydro. The Interconnection System Impact Studies shall indicate if better excitation system than the above is required.

a) Automatic Voltage Regulator

The synchronous generator excitation system shall be equipped and operated with an AVR set to control the generator terminal voltage. BC Hydro may request the AVR to be equipped with a line drop compensation (LDC, also known as reactive drop compensation, RDC) circuit to regulate a virtual location 50-80% through the step-up transformer reactance. Operating the AVR on power factor regulation mode is not allowed.

The AVR shall be capable of automatically maintaining the generator steady state terminal voltage, without hunting, to within plus or minus 0.1% of any set point. The set point range shall be a minimum of from +10% to -20% of the rated terminal voltage of the generator. For testing purposes, a control range of +20% to -30% should be available although the generator and excitation equipment are not required to be capable of continuous operation at these extreme terminal voltage levels.

b) Excitation System Limiters

Excitation limiters shall be coordinated with the generator protective relay settings in such a manner that limiters shall operate before the protective elements with sufficient margin and shall meet the following requirements:

(a) Limiter settings[4] shall not restrict the generator's operating range (terminal voltage and MVAR limits) to less than 100% of the continuous capability of the equipment.

(b) Limiters shall be able to control the excitation system output to avoid unnecessary operation of the generator's protective relays in the event of any sudden abnormal system condition.

(c) Limiters shall be instantaneously reset except for the ones whose designs include modeling of machine thermal characteristics. Limiters shall be "take-over" type and "summing" type limiters are not allowed.

(d) Limiters shall not switch the excitation system from automatic to manual voltage control.

c) Power System Stabilizer

A Power System Stabilizer (PSS) shall be provided for the synchronous generator according to WECC Policy Statement on PSS. The GO shall provide BC Hydro with information on the type and model of PSS for each generator. BC Hydro will conduct studies at the GO's cost to determine the optimum PSS settings that will be implemented and confirmed by field tests during the commissioning of each generator.

[4] This requirement does not apply to the under-excitation limiter (UEL) which is intended to restrict the unit's operating range within the generator capability curve.

PSS shall be kept in service while synchronized unless under the circumstances exempted in the WECC VAR-501-3.1 Requirement R2.

BESS Hybrid Plants

BESS and its hybrid plant shall be capable of providing dynamic voltage control of POI voltages during discharging or charging operations and transition from one mode of operation to the other.

6.4.5 Governor Requirements and Frequency Control

All new generation resources shall be equipped with the capability for frequency control. Any request for exception shall be reviewed and accepted by BC Hydro.

Synchronous Generating Facilities

Governors shall comply with Section 4 of IEEE Standard 125 "IEEE Recommended Practice for Preparation of Equipment Specifications for Speed Governing of Hydraulic Turbines Intended to Drive Electric Generators" and with Section 4 of IEEE Standard 122 "IEEE Recommended Practice for Functional and Performance Characteristics of Control Systems for Steam Turbine-Generator Units." Similar performance requirements shall apply to all types of prime movers (including reciprocating combustion engines and gas turbines). In addition, the governor shall:

- Have speed governors installed on the prime movers of all generators;
- Have governor droops normally set at 5%, particularly for hydro units, and the droops may be lowered to no less than 3% for special needs; Droop setting of more than 5% is not allowed.
- Have governor dead-bands shall not exceed +/-0.036 Hz; and
- Be capable of providing immediate and sustained response to abnormal frequency excursions.

Provide sufficient control actions to damp the frequency oscillations. Damping shall be set in such a manner that, for a +1% frequency step, dynamic response of one single overshoot with the next undershoot less than 5% in amplitude of the first overshoot and shall reach steady state value of +/- 0.1% in amplitude, in no less than 50 seconds when the unit is online (unit circuit breaker is closed).

IBR Plants

IBR Plants shall have the capability to provide primary frequency response (active power-frequency control). IBR Plants shall deliver that primary frequency response (PFR) to the grid when in an operating condition capable of such response. Reserving generation headroom to provide frequency response to underfrequency events is not required. However, resources should respond to over-frequency excursion events by reducing active power output in accordance with the frequency droop settings.

The active power-frequency control for PFR should use a proportional droop characteristic with deadband settings the same as specified above for synchronous generators.

BESS and its AC-coupled BESS hybrid Plants shall have the capability of providing active power-frequency control with the same droop settings, rate of response, and deadbands during charging or discharging, provided it is within the capability of the SOC. The transition between discharging and charging or vice versa should be seamless without deadband. The DC-Coupled BESS Hybrid Plants shall perform the same except that the response is limited by the rating of common inverter.

In addition, newly installed IBR Plants shall have the capability of providing Fast Frequency Response (**FFR**) to help improve the system frequency response performance. For example, “Virtue Inertia Control” used in WTG-based IBR plants may provide FFR by temporarily extracting energy from the turbine’s rotating mass and inject into the grid for a brief period (in a few seconds or less). For typical performance metrics of the FFR provided by WTG based IBR plants, please refer to Section 6.2.3 of IEEE Standard 2800-2022. BC Hydro will work with the GOs to establish the detailed FFR performance requirements for each individual installation. Exemptions to the FFR requirement may be considered for the plants with technology limitations.

6.4.6 Voltage and Frequency Operation during Disturbances

Power system disturbances due to system events such as faults and forced equipment outages expose connected generators to oscillations in voltage and frequency. It is important that lines and generators remain in service during those transient oscillations that are stable and damped. Over/under voltage and over/under frequency relays are normally installed to protect the generators from extended off-nominal operation.

All IBR Plants should be configured to provide fault current contribution to support system protection and stability during and immediately following large disturbances. Momentary cessation should not be used within the voltage and frequency ride through curves specified in PRC-024. Use of momentary cessation is not considered “ride through” within the “No Trip” zone of these curves. Any use of momentary cessation should be studied and approved on a case-by-case basis.

a) Frequency

Each GO shall set its applicable frequency protection settings in accordance with NERC PRC-024 Attachment 1 as per the western interconnection boundaries table. PGFs that are part of the BES should follow all requirements and measures of NERC PRC-024.

Generators that participate in “Local Island” conditions as described in section 9.3 may have specific off-nominal frequency requirements, which BC Hydro will specify.

As well as the under and over-frequency relays applied as part of generator protection, power quality protection (described in section 7.1.5) must also coordinate with the limits of operation.

b) Voltage

Each GO shall set its applicable voltage protection settings in accordance with NERC PRC-024 Attachment 2 as per the western interconnection boundaries table. PGFs that are part of the BES should follow all requirements and measures of NERC PRC-024.

It is not necessary to have settings for each of the values given in tables in NERC PRC-024 standard.

Note that for all IBR plants, the ride-through requirements specified above would need to be updated to align with the applicable requirements in a newly proposed NERC standard PRC-029-1 once it is adopted in BC. All existing and newly installed IBR plants subject to the proposed PRC-029-1 standard shall comply with the updated ride-through requirements once the standard comes into effect in BC.

Contingency and RAS Requirements

The GO is responsible for determining and adequately designing and protecting its generating plant against the impacts of switching operations and contingencies in the Transmission System such as:

- Load rejections will cause over-speed and over-voltages on the PGF. The amount of over-speed and over-voltage will be a function of the electro-mechanical and system parameters of the interconnected system and the PGF.
- Self-excitation can occur when an islanded or unloaded Transmission System, which, if left connected to the PGF, presents a capacitive load in excess of the synchronous generator's capability to absorb it. The PGF could be damaged by the resulting over-voltage if the PGF is not quickly disconnected from the Transmission System. BC Hydro will provide data on the maximum line capacitive admittance for line sections that may be left connected to the PGF by switching events.
- Resonance or near resonance may occur when an Islanded Transmission System is left connected to the PGF. This will cause unacceptably high transient over-voltages unless corrective measures are provided.

To prevent the PGF from being damaged by reclosing operations, the PGF will be disconnected from the Transmission System prior to BC Hydro reclosing the circuit.

Acceleration of the PGF during faults on nearby transmission lines could cause the plant to slip out of synchronism from the Transmission System. BC Hydro will take measures to reduce the probability of such events but if a loss of synchronism occurs, it is the responsibility of the GO to detect the loss and immediately trip off the affected generators.

RASs may be required to mitigate the impacts of contingencies to the Transmission System; e.g., generation shedding, generation run-back, etc. RAS requirements may necessitate an increase in telecommunications requirements to ensure that reliability, delay, and bandwidth are sufficient for RAS participation.

6.5 Transformer Requirements

The GO shall coordinate transformer ratio and tap settings with BC Hydro to optimize the reactive power capability (lagging and leading) that can be provided to the Transmission

System. Refer to IEEE Std. C57.116, *Guide for Transformers Directly Connected to Generators* for guidance. BC Hydro will provide the expected normal operating voltage range at the POI to assist in ratio selection. The ratio should not be based solely on the nominal voltage or the voltage class of the POI.

The Transmission System must normally be effectively grounded. This requires all PGFs connect to the Transmission System via transformers to have solidly grounded HV windings and with transformers configured, so that the HV winding is an effective source of zero sequence current. A HV grounded WYE to LV Delta is the conventional optimum configuration (See section 5.4 for more details). Other transformer winding configurations such as auto-transformers may be necessary and appropriate where there is an underlying collector network, and the POI has suitable network switching to permit selective system protective relaying.

Transformers, their auxiliaries, controls, protection, and operating procedures must allow the generator to deliver its continuous reactive power capability. Transformers must also be able to withstand the voltage and frequency excursions associated with load rejection and system separation events.

BC Hydro recommends generator step-up transformers to have off-load taps on the secondary (HV side) with a minimum range of two 2.5%-steps above and two 2.5%-steps below the normal delivery voltage. BC Hydro must approve the selected voltage, winding connections, and adjustment range for each interconnection.

6.6 Transmission Line Design Requirements

Transmission line design requirements apply to foundations, structures, hardware, conductors, overhead design, electrical effects, Right of Way, etc. The specific requirements will be a function of the application. In all cases the GO shall identify the registered Professional Engineer of record responsible for the design.

Transmission lines must comply with Good Utility Practice to ensure satisfactory operation and to avoid adverse impacts on the safety and security of the BC Hydro facilities. As a minimum requirement the design must meet the latest version of CSA standard CAN/CSA C22.3 No.1-10 Overhead System

Where the transmission line is a tap connection (69 or 138kV) to the BC Hydro System, the GO is encouraged to design their transmission line to meet or exceed BC Hydro reliability related line performance requirements which include, but are not limited to the following design requirements:

(a) Electrical clearance requirements are per BC Hydro Engineering “41” Series Transmission Engineering Technical Standards, Procedures and Guidelines;

(b) Right of way width and clearing are according to BC Hydro standards (for greater detail, see the “Transmission Line Asset Transfer Requirements Design and Construction Guide”).

(c) Hazard assessment outcomes are implemented.

(d) The GO shall provide a permanent, all-weather access road to the disconnect switch(es) at the tap point, including all necessary property rights for BC Hydro to use the access on BC Hydro's form of agreement.

The GO shall provide BC Hydro a copy of the design of the line, including the Plan & Profile drawings and a geographic data file of the line route.

Segments of the GO's line that cross or run parallel and impacts BC Hydro's infrastructure or rights of way are to be reviewed under BC Hydro's property referral process.

Although there is no requirement on BC Hydro to take over ownership and operation of a GO line connecting to the BC Hydro System, there may be circumstances which warrant such a transfer of assets. For a transfer of ownership of a transmission line, BC Hydro may, at its discretion, impose additional technical and non-technical requirements and submittals above and beyond those detailed in the subsections below and this document in general.

6.6.1 Environmental Considerations

Construction of transmission lines shall be performed in an environmentally responsible manner in accordance with the following key commitments of BC Hydro's Environmental Responsibility Principles and the Environmental Management System (**EMS**):

- Avoid and mitigate environmental impacts
- Meet or exceed environmental regulatory requirements

BC Hydro expects that if environmental incidents occur, they shall be mitigated in a duly diligent fashion. An environmental assessment is required and an environmental management plan, which has been agreed with the appropriate regulatory agencies, is required before construction commences.

6.6.2 Connection to the BC Hydro System

The constructed transmission line is subject to the following requirements prior to acceptance by BC Hydro for connection to the Transmission System:

- Approval by the electrical inspector or the authority having jurisdiction
- Inspection of transmission line at POI by BC Hydro
- Defects identified by inspection shall be corrected prior to acceptance
- Assurance by the named Professional Engineer of record that the constructed transmission line complies with the design and a statement that the design has met all the applicable industry standards and regulations.

6.6.3 Line Performance

Single Circuit Connection

Depending on network topology and PGF size, acceptable line performance can be achieved to avoid generators separating from the system by applying shielding or line arresters, and for EHV lines single-pole reclosing protection shall also be applied.

Multiple Circuit Connection

There is a possibility of simultaneous or near simultaneous faults from lightning strikes where multiple circuits share a common right-of-way. Therefore, shielding or line arresters are applied, and for EHV lines single-pole reclosing protection shall also be applied.

7. Protection Requirements

Replacement or modifications of protection systems within the BC Hydro System may be required due to the addition of the PGF. These requirements are the responsibility of BC Hydro.

7.1 General Requirements

The protection system installed by PGF must be able to detect power system faults both within the PGF facility and within a section of the BC Hydro System. The protection system should also detect abnormal operating conditions such as islanding, equipment failures etc. Special relaying practices may also be required for system disturbances, such as undervoltage or underfrequency detection for load shedding or reactive device switching.

7.1.1 Regulatory Requirements

All PGFs that are part of the BES, including inverter-based resources, are subject to the NERC reliability standards based on the applicability of each reliability standards to that resource.

Protective relays and their settings are required to follow various regulatory requirements such as NERC and WECC standards. These requirements are subject to change. BC Hydro is not responsible for the failure of a customer's protective relay systems to meet these requirements.

7.1.2 Protection for Internal Faults

The PGF's protection shall have adequate sensitivity to detect and clear all electrical faults in the PGF, and shall coordinate with other BC Hydro protection systems, for the present and future (ultimate) fault levels. This protection is generally referred to as "Entrance Protection". Coordination is defined as either:

- Fully selective clearing, in which the PGF's protection clears all faults in the PGF before other relaying within the Transmission System initiates tripping for such faults.

or

- Simultaneous clearing, in which the PGF's protection clears all faults in the PGF simultaneously with the clearing of such faults by Transmission System protection.

Fully selective clearing is normally required for PGF. However, BC Hydro may require simultaneous clearing in certain cases to meet the protection requirements of the Transmission System.

7.1.3 Equipment Rating

The GO's equipment shall be rated to carry, detect and interrupt the present and future fault levels at the PGF. To do this, the GO's station and transmission equipment facilities, including but not limited to all current transformers, potential transformers, secondary cabling, DC system/battery charger, switchboard wiring and protective relays, shall be designed for the ultimate fault duty. (See sections 5.4, and 6.3.4 for further details.)

7.1.4 Unbalance Protection

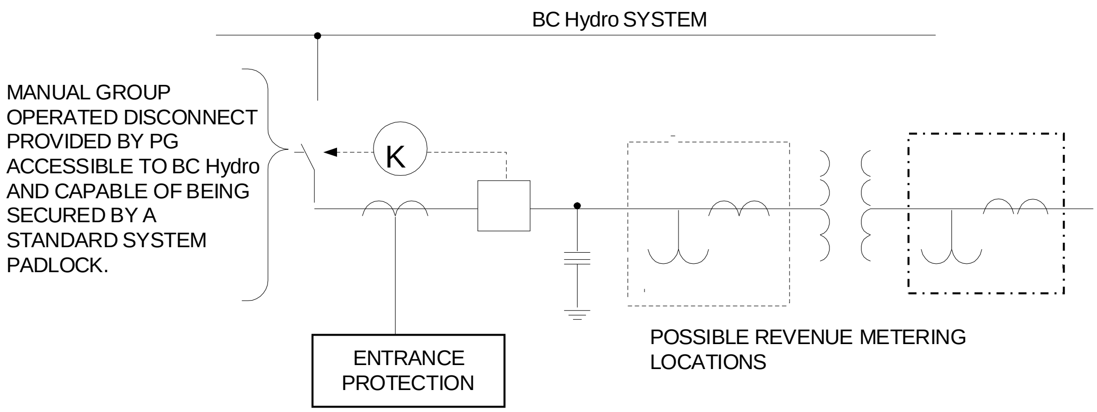
The GO's equipment may be subjected to negative sequence current due to unbalances on the Transmission System. BC Hydro recommends the provision of negative sequence (unbalance) protection (device 46) to protect rotating equipment from excessive and potentially damaging negative sequence current arising from voltage unbalance.

7.1.5 Voltage Protection and Frequency Protection

PGF require voltage and frequency protections. Voltage and frequency protection settings for a generating station connected to the Transmission System must comply per section 6.4.5. Entrance Protection

The PGF entrance circuit breaker shall be included in the entrance protection zone. That is, the relays shall connect to current transformers on the Transmission System side of the circuit breaker, as shown in Figure 5. A PGF that is part of the BES shall have redundant entrance protection systems, preferably dual differential. This will simplify protection coordination with BC Hydro’s protection system.

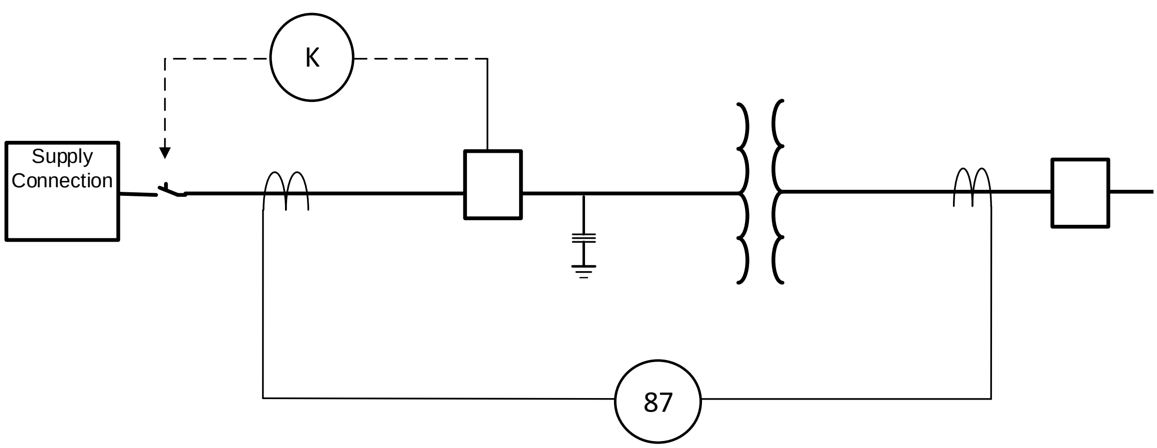
Figure 5: Generic Entrance Protection One-Line Diagram



All GO's metering equipment shall be included in the Entrance Protection zone or in the PGF's internal protection zones. No revenue metering equipment shall be located on the Transmission System side of the Entrance Protection zone unless by special arrangement with BC Hydro.

Figure 6 describes an example installation that meets the minimum requirements for Entrance Protection.

Figure 6: Generic non-redundant Entrance Protection Example



Note that the application of transformer differential protection eases the coordination requirement with protection in the BC Hydro System.

7.2 Transmission Line Protection Requirements

The GO shall provide redundant protection equipment to detect all phase and ground faults on the portion of the Transmission System identified by BC Hydro. Redundancy is required so that the failure of any single protection will not prevent the system from meeting the requirements. Protection relays must be capable of providing trip for faults anywhere on the protected line. Depending on the location and method of connecting to the Transmission System, telecommunications assisted line protection may be required to provide acceptable fault clearing times.

Protection systems must be capable of performing their intended function during fault conditions. The magnitude of the fault depends on the fault type, system configuration, and fault location. It may be necessary to perform extensive model power system tests of the protective relay system to verify that the selected relay works properly for various system configurations. Power system swings, major system disturbances and islanding may require the application of special protective devices or schemes.

Protective and trip relays used in protection systems required to meet Transmission System needs must be approved by the BC Hydro. During fault inception, priority should be given to delivering as much current to the system as quickly as possible to support protective relay systems to detect and clear the fault. Many existing transmission protection systems utilize negative sequence quantities extensively to determine fault direction to operate reliably. IBR negative sequence current contribution models may be required for protection system evaluation. IBR must provide current decrement for a close-in and remote line end 3 phase faults and resistive ground fault for remote line end faults.

IBRs should accurately detect and control the type of current needed based on terminal conditions and respond accordingly to provide a combination of active and reactive current injection.

The GO shall provide breaker failure protection for the entrance circuit breaker.

For line protection at the PGF the following shall apply:

- For pilot schemes, BC Hydro will specify protection schemes. Relaying at the PGF terminal must be of the same type and operating principal as used at the utility line terminals.
- For non-pilot scheme protections, BC Hydro will approve the protection relays. For ease of testing and maintenance, duplicate systems are preferred.

7.2.1 Protection System Settings

It is a PGF's responsibility to implement protection settings to protect, coordinate and meet all applicable NERC and WECC standards. A PGF must not modify settings for its protections without authorization from BC Hydro. A PGF must carry out periodic checks of protective devices it has installed.

7.2.2 Detection of Ground Faults

New GO connection shall provide a source of ground current on high voltage side and any other connection must be evaluated by BC Hydro before permitted per section 4.4.1. Ground fault detection has varying requirements. The availability of sufficient zero-sequence current sources and the ground fault resistance both significantly affect the relay's ability to properly detect ground faults. The same types of relays used for phase fault detection are suitable for ground fault detection. If ground fault distance relays are used, backup ground time-overcurrent relays should also be applied to provide protection for inevitable high-resistance ground fault.

7.2.3 Detection of Phase Faults

The GO shall provide dedicated phase fault protection and trip to clear isolated multi-phase faults on the Transmission System using differential relaying (87), impedance relaying (21), directional inverse time over-current relaying (67), or inverse time over-current relaying (51) as appropriate to the installation.

7.2.4 Breaker Failure Protection of the PGF HV Circuit Breaker

Breaker failure protection shall be provided for failure of the main PGF HV circuit breaker to clear for a transmission line fault.

Breaker failure protection shall take one of the following forms:

- CB auxiliary switch scheme;
- Current-based scheme; or
- Back-up relaying within the PGF.

BC Hydro does not intentionally provide breaker failure back-up tripping for the case of the main PGF circuit breaker failing to clear a PGF facility fault. For situations where telecommunications facilities are applied for other reasons (for example transmission line protection), a spare signal channel may be available to provide back-up tripping. Provision for such a facility will be determined by BC Hydro and evaluated on a case by case basis.

7.2.5 Voltage and current transformers

Current and voltage transformers must be installed on each of the three phases of the transmission line, used to supply telemetry to the power line protection systems installed to protect the Transmission System.

7.2.6 Requirements regarding event recorders

Line protection relays have event and disturbance recording capabilities. The PGF should provide a communications link for remote interrogation of the line protection relays. Alternatively, the PGF may extract and archive data recorded by the line protection relays protecting the Transmission System and supply this data to BC Hydro upon request following any event. Additionally, the PGF must retain these recordings by systematically collecting them after each line protection relay trip. Within a reasonable timeframe, the PGF must forward the COMTRADE format files and event recordings to BC Hydro.

SER devices should be sized to capture and store multi event records and logs. SER event records can be triggered for many different reasons but at minimum, shall include the following:

- Event date/time stamp (synchronized to common reference, e.g., Coordinated Universal Time [UTC])
- Event type (status changes, synchronization status, configuration change, etc.)

- Sequence number (for potential overwriting)

7.2.7 Prevention of Energization of Ungrounded Transmission Line by PGF

As indicated in section 5.4.1, the PGF shall provide a source of ground fault current to the high voltage side. However, for existing installations that are HV delta connected (no source of ground fault current to high voltage side), the PGF shall be disconnected immediately upon de-energization (open ended or loss of ground source) of the BC Hydro transmission line to avoid the transmission line becoming un-grounded. A direct transfer trip from the BC Hydro end of the transmission line to the PGF is one method to prevent ungrounded operation, which may be costly. A study will be required.

A sample installation of GO's transmission line protection is shown in Figure 7 below.

Figure 7: Sample Installation of Minimum Transmission Line Protection

Figure 7- 1: PGF Line Protection Utilizing Multi-Function Distance Relays*

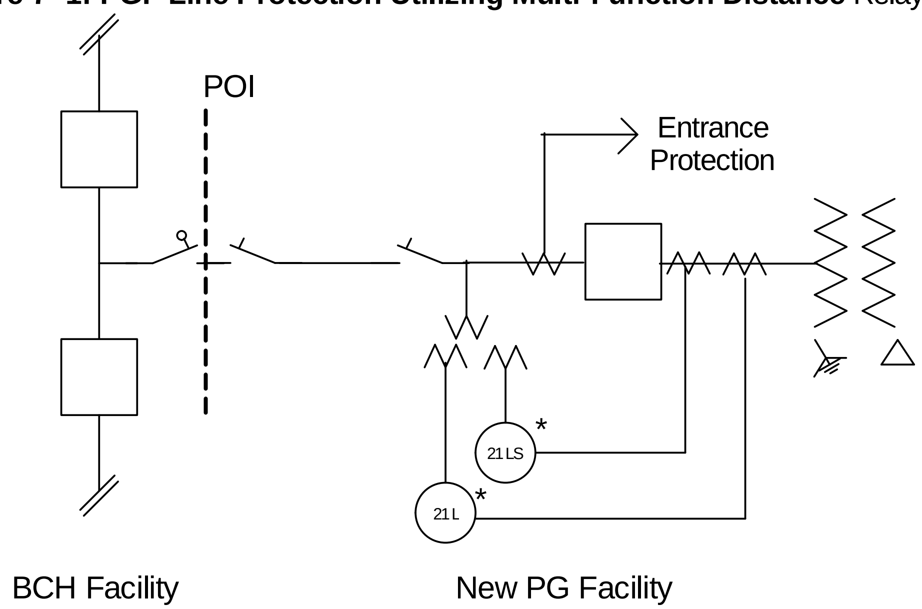
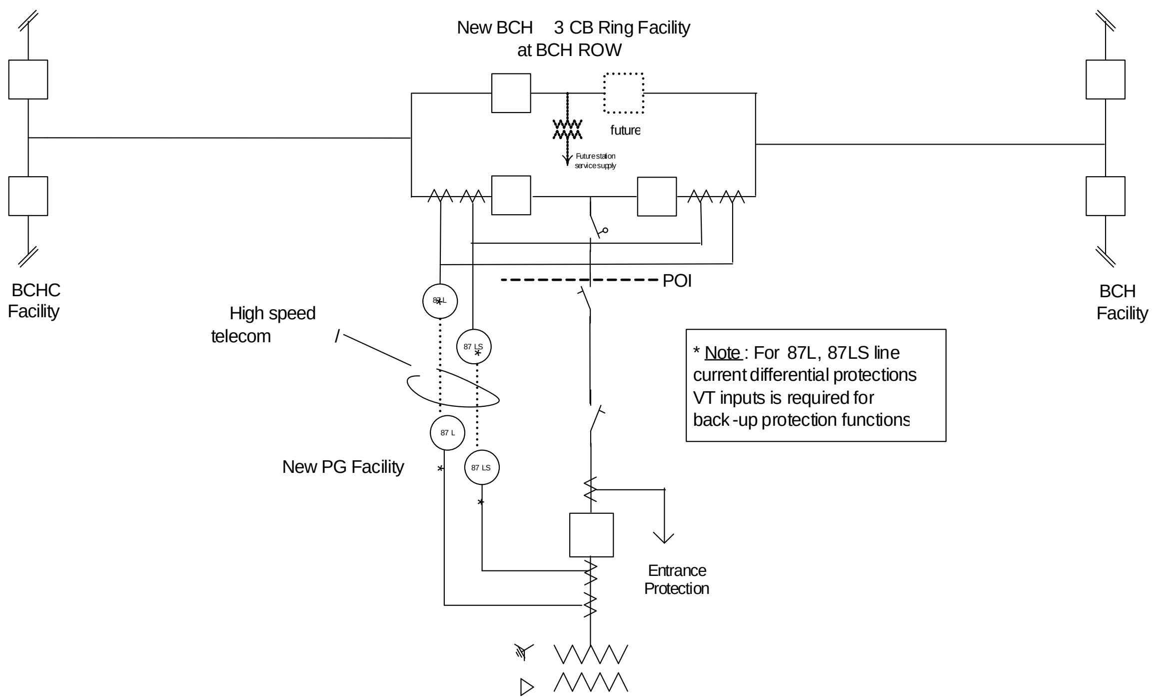


Figure 7 - 2: PGF Line Protection Utilizing Line Current Differential Protection



7.3 Power Quality Protection

The GO shall provide under-voltage, over-voltage, under-frequency, and over-frequency power quality protection that complies with BC Hydro, BCUC BCMRS, and WECC requirements. Duplicate power quality protection may be required.

The purpose of power quality protection is to ensure acceptable quality of power to other customers in case an Island is inadvertently formed. It is applied to the HV VTs at PGF. Depending on application and settings, it may prevent Islands from being formed if the connected load in the Island is significantly different from the connected generation. This application must not violate the voltage and frequency ride through requirements of section 6.4.6. If speed of operation is an issue, other measures may need to be taken as described in sections 5.7.3 and 5.7.4.

As well as meeting quality of power issues, the protection shall also meet the requirements of the voltage and frequency limit criteria described in section 6.4.6.

7.4 Under-frequency Load Shedding Protection

If a PGF becomes connected as a load for any period of time or requires station service, there may be a requirement for under-frequency load shedding. The requirements will generally follow the requirements of the WECC. BC Hydro will determine the specific requirements in each instance.

7.4.1 Frequency Relay Requirements

Relays with inverse time vs. frequency operating characteristics are not acceptable. Relays shall be based on solid state or microprocessor technology and shall have a dropout time of 2 cycles or less.

7.5 Station Service Batteries / Chargers / DC Supplies

Station service batteries shall be suitable for station applications, having a long life when on float charge with no load cycling. In general, this requires the use of lead calcium batteries.

GOs shall ensure that the continuous DC supply voltage rating of any relay or its associated power supply is not exceeded due to sustained over-voltages on the DC supply bus. Common causes of high, sustained over-voltages are:

- Battery chargers at their equalize setting,
- Battery chargers connected to the DC supply bus without the station batteries, and
- Battery chargers set in the constant current charging mode.

If there is any possibility that the DC rating of a relay will be exceeded, a passive voltage regulator of suitable rating shall be applied to each relay to limit the DC voltage to within that relay's DC rating.

Dual station batteries may be required for power protection and control equipment for PGF connecting to the Main Transmission System if such connections are permitted. BC Hydro will determine the requirement of dual station batteries at the time of interconnection studies.

The DC supply shall:

- Supply power circuit breaker control circuits from dedicated and independently protected DC circuits,
- Supply those physically separated protection systems that are intended to back each other up from dedicated and independently protected DC circuits,
- Provide one under-voltage relay, with time delay, to provide an alarm for battery charger failure or loss of AC supply, and
- Provide one under-voltage relay with adjustable setting capability in a scheme[5] that:

    (i) Operates at least 5 VDC above the minimum acceptable voltage to operate the circuit breaker and associated protection and control circuitry,

    (ii) Operates to shut down the generator and open the HV circuit breaker to disconnect the PGF from the Transmission System, and

[5] This under-voltage tripping function is not required if the PGF is manned 24 hours a day. Coordination of the voltage settings and time delays is required between alarming for battery charger failure or loss of ac supply and under-voltage tripping.

(iii) Has delayed trip initiation, not to exceed 1 minute, to override temporary voltage dips.

8. Control and Telecommunications Requirements

8.1 Telecommunications

8.1.1 General

Control and telecommunications facilities, including those for protective relaying and RASs, may be required at the PGF and within the Transmission System for safe and efficient operation of the power system and for the safety of personnel. This may include the upgrade of existing transmission and interconnected facilities. All facilities and equipment defined in the sections 8.1.2, 8.1.3 and 8.1.4 require BC Hydro approval to ensure that applicable standards and required functionality, reliability, and availability of spares are met. In some cases, specific equipment may be required to ensure compatibility with existing equipment such as SCADA and other data monitoring systems. BC Hydro may modify its control and telecommunications requirements when detailed GO equipment information becomes available or changes. All costs to install, maintain and support communication access are the responsibility of the GO.

8.1.2 Telecommunications Media

Telecommunications media alternatives for the PGF may include dedicated or leased optical circuits, power line carrier, microwave radio, UHF or VHF radio, satellite, and cellular wireless data. Two-way telecommunications media will generally be used. Depending on the power capacity, required availability of the function, location, and other circumstances, BC Hydro will specify one, and in some cases more than one, acceptable telecommunications media which may be used for each given circuit and function. Due to the evolving nature of the communications industry, telecommunications solution requirements will be evaluated on a case-by-case basis. Due to the individual purpose or system impact of each circuit or function, there is an expected minimum availability performance. For each circuit associated with system operating functions, the acceptability and prescription of telecommunication solutions are based on expected minimum annual availability. BC Hydro may order the suspension of the transmission voltage interconnection if for any reason the expected minimum annual availability fails to be met. In most cases, the expected minimum availability value is based upon the maximum generator (or load) power delivery. These expectations are:

0 to 10 MW	95%
10 MW to 30 MW	99%
30 MW to 70 MW	99.5%
70 MW or greater	99.7%

For each circuit or function associated with a teleprotection system or RAS, BC Hydro specifies the minimum acceptable annual availability and maximum acceptable repair interval to be met at all times and as a condition of continuing transmission voltage interconnection operation. In most cases, the minimum annual availability is specified as corresponding with a WECC level of availability. Most commonly specified are WECC Level 1 (99.95% with facility and equipment diversity), and WECC Level 3 (99.5% specified with or without facilities and equipment diversity).

Whenever metallic pairs are used, appropriate telecommunications Entrance Protection shall be provided since the station ground potential can rise to hazardous levels above remote ground potential during a power system fault. Telecommunications Entrance Protection provides safety to personnel, prevents damage to equipment, and allows continuous use of the telecommunications media and the attached equipment during and after power system faults. This equipment is the responsibility of the GO and shall meet the public carrier and BC Hydro safety and protection requirements.

If power line carrier facilities are used, appropriate carrier accessories are required. These include wave-traps, line matching units and carrier coupling devices (often CVTs with carrier accessories), both at the PGF and at the BC Hydro station having the other carrier terminal.

In cases where the connection is a tap into a circuit that has power line carrier operating on it, a wave-trap is required at the tap point on phase/s of the tap, which could otherwise attenuate the existing carrier signal on the BC Hydro System. In some cases, specialized carrier bypass facilities will be required.

If leased fibre circuits or privately constructed fibre optics are used, the use of all-dielectric fibre cable, not containing a conductive trace wire, is required at the entrance to the PGF.

8.1.3 Telecommunications System for Operating Functions

BC Hydro will specify the type of equipment required, the interface points and other characteristics required at the interconnection study stage. Facilities, which may be required initially or in the future at the PGF, communicating with BC Hydro's Control Centres for real-time operation of the power system, include:

- Digital and/or analog telemetering equipment,
- Remote control, to enable dispatching of power,
- Status/alarm reporting equipment to satisfy WECC guidelines, comply with BCUC regulations, inform grid operational decisions, or for contractual obligations.
- Equipment for generation shedding or other RAS actions,
- Voice telecommunications for operating,
- Data telecommunications for access to SCADA equipment,
- Telecommunications media for the above, and
- Suitable battery and charger systems for the above.

The first two items above are often combined in one or more SCADA remote terminal units (**RTUs**).

Separate telecommunications facilities are required to interrogate the main revenue meter, backup revenue meter, and the PPIS equipment. Commercial IP based solutions are preferred any may include cellular wireless data service, satellite terminal, or fibre business Internet VPN. Dialup is not suitable but may be accepted under a case-by-case basis. In some cases, use of the telecommunications facilities to BC Hydro for operating functions may be considered where commercial services are not available.

To ensure compatibility of design and operation, BC Hydro will provide technical requirements to the GO for the telecommunications equipment at the PGF needed to transmit data from PGF to BC Hydro.

BC Hydro will not provide high voltage telephone entrance protection equipment.

8.1.4 Telecommunications System for Teleprotection Functions

Telecommunications assisted protection facilities may be required for power system protection functions at the PGF and between locations affected by the PGF connection. BC Hydro will specify the type of equipment required, the interface points and other characteristics required at the interconnection study stage. The required facilities may include:

- Specialized high-speed teleprotection signals for transmission line protection,
- Specialized high-speed transfer-trip teleprotection signals for functions such as transformer protection, reactor protection, over-voltage protection, circuit overload protection, breaker failure protection, and the initiation of generator shedding or other RAS actions,
- Telecommunications media for the protection facilities, and for remote access to electronic relays, event recorders and fault recorders (used for the analysis of power system disturbances), and

The battery and charger system for which parameters and size will be determined on a case-by-case basis. Some systems may be specified as 24V floating or 48V positive ground. The battery reserve will typically be 8 hours for sites with easy access, or 24 hours for sites without easy access.

To ensure compatibility of design and operation, BC Hydro will provide technical requirements to the GO for the telecommunications equipment at the PGF needed to transmit and receive teleprotection signals between the PGF and BC Hydro.

Where a leased service is used to carry teleprotection, the GO will be the customer of record. To maintain this function, the GO needs to monitor the teleprotection system, detect faults in the system including the teleprotection channel, and whenever leased service failure occurs, to report this to their service provider. Teleprotection system failure typically results in the PGF being ordered off-line until the system is restored.

BC Hydro will not provide high voltage telecommunication entrance protection equipment.

9. System Operating Requirements

9.1 Generation Scheduling and Control

Any new generation being integrated into the BC Hydro System shall adhere to the scheduling requirements in the prevailing tariff under which it takes transmission and ancillary services from BC Hydro.

BC Hydro's Control Centres will be the main operations contact for all entities with generation connected to the BC Hydro System.

GO is responsible for providing, or causing to be provided, generating schedules to BC Hydro. The schedule details shall be agreed upon with BC Hydro's Control Centres. BC Hydro operators may require real time changes from the agreed schedule when necessary to maintain system reliability. The GO will retain final responsibility for the plant.

If the GO's generation is controlled in real time by BC Hydro, the GO shall provide full SCADA facilities, including alarm monitoring for each generating unit to a BC Hydro's Control Centre. If the GO's generation schedule is dispatched in real time by BC Hydro, the GO shall provide to a BC Hydro's Control Centre direct control or 24 hour telephone access to a continuously manned GO control centre via a dedicated telephone line. Within an agreed time, the manned GO control centre or the remote control facilities provided to BC Hydro's Control Centre shall be able to:

- Start-up, synchronize and fully load the GO's available generators (synchronization will normally be accomplished using the generator unit breakers),
- Shut down the GO's on-line generators,
- Setup RASs at the PGF if it is required to participate in generation shedding or run-back,
- Change the output of any of the GO's on-line generators according to an accepted schedule, and
- Change the mode of operation of any of the GO's generators (e.g., from generating to synchronous condenser mode if the units have the capability.)

BC Hydro will curtail generator's output for reliability reasons in the BC Hydro System. The PGF shall be able to complete the curtailment amount within 10 minutes of notification to the GO or Generator Operator at any time (7x24). Otherwise, there may be requirement to implement automatic curtailment in accordance with instruction or control signal from the BC Hydro System operator. Controls for curtailment or dispatch may be several, for a series of blocks of generation capacity to be curtailed or dispatched.

The real power output of the WGF is required to be adjustable during start-up. The normal maximum ramp up rate shall be the **lesser** of, (a) 10% of the aggregated MW capacity of the WGF in MW per minute, or (b) 80 MW per minute. On a case by case basis, BC Hydro may specify a maximum WGF power ramp down rate if there is any adverse impact to the control performance or reliability of the BC Hydro System.

9.2 Remote Operations

If the PGF is operated remotely by BC Hydro's Control Centres, BC Hydro will require, in addition to the direct control of the generators listed in Section 9.1, the ability to monitor alarms and operate the PGF's generator switchyard and transmission system. Detailed requirements will be specified in a separate agreement between BC Hydro and the GO.

9.3 Generation Islanding

Local Islanding

For those generators interconnected to the BC Hydro System through a tapped transmission line, a Local Island is created when the breakers at the ends of the transmission line open. This leaves the generator and any other loads that also are tapped off this line isolated from the power system. Delayed fault clearing, over-voltage, ferro-resonance, extended under-voltages, etc., can result from this Local Island condition and shall not be allowed to persist. Special relays and relay settings are required to disconnect the generator(s) rapidly in the Local Island. (See sections 6.4.6 and 7.4 for more details.)

Note however a Local Island could persist as long as PQ and frequency are within acceptable limits.

To protect the BC Hydro System and its customers against these extended voltage and frequency excursions and degraded service, special relays to detect these conditions and isolate the local generation from the BC Hydro System are required as per Sections 7.3 and 7.4. These relays shall not be set with such short time or to narrow an operating window as to encroach on the frequency and voltage limit operating criteria described in section 6.4.6. For cases where the requirements conflict, other measures may need to be taken such as direct transfer tripping form the BC Hydro source station(s) to the PGF.

Large Area Islanding

Area Islanding is a condition where the power system splits into large areas of isolated load and generation groups, usually when breakers operate for fault clearing or in a RAS for system stability. Generally, the "islanded groups" will not have a stable load to generation resource balance. Protective relaying that responds to large frequency and voltage fluctuations may trip the loads and/or generators during an islanding condition after a disturbance. However, it is possible that, under unique situations, governor control can establish a new equilibrium in an islanded group.

BC Hydro does not generally allow islanding conditions to exist for prolonged periods. On rare occasions a controlled, temporary, area-wide separation, such as islanding of the North Coast area may be required for certain operation and maintenance purposes.

Those PGF that could be used for Area Island operation will be required to be equipped with remote control operation capability from the BC Hydro Control Centre.

9.4 Normal and Emergency Operations

The GO shall provide a 24 hour contact for normal and emergency operations. Communications between the GO and BC Hydro will be specified in a joint operating order.

9.5 SCADA, Telecommunications and Control

BC Hydro may require telemetering equipment for readings such as MW, MVAR, MW.h, I, and kV. This data is supplied to BC Hydro Control Centres in DNP 3.0 format. All data provided in response to poll messages transmitted by BC Hydro must be completed in less than or equal to 2 seconds.

The specific requirements will depend on the size of the plant, location, strength of the Transmission System at the POI, other generation in the area, and other factors. Telemetered quantities and examples of communication media are summarized in Table 8. Generally speaking, increasing plant size results in additional telemetered quantities and improved communication performance with respect to latency, data rate, and availability. Examples of communication media will range from share services offering best efforts performance such as cellular, Internet, etc to dedicated facilities providing assured performance. These requirements may be increased by BC Hydro T&D System Operations if deemed to have safety or significant operational impact. The evolving nature of the communications industry will require evaluation of communications media alternatives on a case-by-case basis. Final requirements will be specified in the PIR.

These SCADA requirements may be waived for standby generators that parallel BC Hydro System only infrequently or for short periods of time. See section 8.1.2.

Note that dialup is not suitable and analog 4-wire copper lease lines are no longer offered by most service providers.

The expected minimum availability performance of the SCADA is the same as the telecommunications availability performance described in Section 8. The acceptability and prescription of SCADA solutions are based on expected minimum annual availability. BC Hydro may order the suspension of the transmission voltage interconnection if for any reason the expected minimum annual availability fails to be met.

Table 7 SCADA Quantities and Communication Examples

Plant Size	Telemetered Quantities	Examples of Telecommunication Media
<10MVA	Plant level: MW, MVAR, MW.h (hourly), kV, interconnection status. Line telemetry at POI (if different than plant): MW, MVAR, kV.	Latency, data rate, and availability as best efforts e.g., cellular
10-30MVA	Unit level: MW, MVAR, kV, MW.h (hourly), connection status, running status; PSS status if equipped with PSS; AVR status if equipped with AVR. Line telemetry at POI (if different from unit aggregate): kV, MW, MVAR	Latency, data rate, and availability improved, as best efforts e.g., dual cellular or satellite
30 - 75MVA	Unit level: MW, MVAR, kV, MW.h (hourly), connection status, running status, PSS status if equipped with PSS, AVR status if equipped with AVR, tap changer position (if equipped with on-load automatic tap changer), low side kV (if equipped with on-load manual tap changer). Line telemetry at POI (if different from unit aggregate): MW, MVAR, kV.	Low latency, high data rate, as best efforts; and assured high availability e.g. business grade Internet at the GO plant
>75MVA	Same as 30 - 75MVA	Assured low latency, high data rate, and high availability e.g. commercial lease or privately constructed connection from GO to BCH; fibre, microwave, power line carrier, etc.

In addition to the requirements identified in Table 7, wind generators also are required to provide the following:

- The intelligent electronic device (**IED**) must be capable of providing all required data at a one second polling frequency and must be capable of supporting unsolicited reporting.
- Data requirements at the collector bus for each of the WGF feeders[6] in addition to what is listed in Table 7 in section 9.5:

[6] A feeder consists of several wind turbine generators in a wind generation facility that is electrically connected in parallel on a collector bus which is then connected through a step-up transformer to the Point of Interconnection. A wind generating facility may have one of more feeders in its configuration.

- Average wind speed (every 10 seconds, if required, for the WTGs connected to the feeder); and
- Average wind direction (every 10 seconds, if required, for the WTGs connected to the feeder).

The following additional information from each meteorological tower at multiple elevations (to be determined between the WGF owner and BC Hydro) for wind generating sites shall be made available through telemetry to the BC Hydro System operator:

- Wind speed (every 10 seconds);
- Wind direction (every 10 seconds); and
- Relative humidity (every 30 min).
- Status of circuit breakers for transformers and all shunt compensation devices located at the WGF substation.
- The tap position of the substation transformer at the WGF, if fitted with on-load tap-changers.
- For collector systems in WGF with more than one feeder and individual switching devices: feeder status, feeder kV, feeder MW, feeder MVAR and feeder MW.h. Each feeder may be represented and modeled as a single generator.

9.6 Other Requirements

9.6.1 Phasor Measurements

Realtime GPS time synchronized phasor measurements are required for plants connecting at 138 kV or above and with a rating of 75 MVA or greater. Required measurements are positive sequence line kV and I at a minimum 30 samples per second using the IEEE C37.118 protocol over an IP connection on a suitable communications media outlined in Table 6.

9.6.2 Additional Requirements

Other operating and technical requirements will be determined by interconnection studies and in negotiations or consultations between the GO and BC Hydro when the need arises.

10. Commissioning Requirements

10.1 General

The GO has full responsibility for the inspection, testing, and calibration of its equipment, up to the POI, consistent with the SGIA.

BC Hydro System Operating Order 1T-35 describes the commissioning process. A copy of the order is available upon request for GOs.

Prior to commissioning, BC Hydro requires a declaration from a member of the Engineers and Geoscientists British Columbia, or a holder of a license issued by that Association, stating that the PGF has been designed, constructed, and tested in accordance with:

(a) Technical interconnection requirements stated in this document;

(b) The project specific requirements as stated by BC Hydro in the SGIA

(c) Good Utility Practice

BC Hydro requires the following for the commissioning of the GO's equipment:

(a) Performance of all commissioning by competent personnel,

(b) Compliance with the various levels of Declarations of Compatibility and Commission Notice to Energize, as required, prior to loading, synchronizing and operating. These requirements refer to key aspects where BC Hydro must be confident of the correct operation, settings, calibration and/or installation of equipment. This may include, but is not limited to, facility information, equipment and facility ratings, generator performance, protective relaying, telecommunications, and revenue metering. Inspection and testing shall confirm the compatibility of the GO's equipment and controls with the BC Hydro System where applicable,

(c) Testing to confirm the safe, reliable and effective operation of all equipment in the PGF under normal and abnormal conditions,

Assignment of a BC Hydro Field Coordinator to the installation in order to assure compatibility by:

- Witnessing any part of the commissioning tests,
- Requesting additional testing, or
- Conducting BC Hydro's own testing.
- Correction of any deficiencies identified during commissioning before the interconnection is approved for operation, and
- Submission of a copy of the commissioning reports signed and sealed by a Professional Engineer.

10.2 Protection Equipment

Commissioning of protection equipment shall include but not be limited to:

- Ratio, phase and polarity testing of current transformers and voltage (potential) transformers,
- Calibration checks of each protective relay by injecting the appropriate secondary AC quantities,
- Functional testing of the protective relays to circuit breakers and telecommunications equipment. Testing shall include minimum operating point verification for relays,
- Functional and timing testing of RAS facilities, such as generation shedding facilities, and

- Load tests of protective relays immediately after initial energization.

The settings applied to selected relays shall be as determined and/or reviewed by BC Hydro.

10.3 Telecommunications Equipment

Functional end-to-end testing of telemetry, protection, alarms, voice, and related equipment is required.

10.4 Operating, Measurement and Control Systems Commissioning Requirements

BC Hydro requires the following testing of the control and measurement systems:

- Testing to prove the proper operation of synchronization controls, governors, excitation systems, voltage regulators, PSS systems and other control schemes,
- Testing to confirm the ratio, phase and polarity of non-protection instrument transformers,
- Testing of the revenue metering in accordance with Measurement Canada requirements, and

BC Hydro may require a representative to witness the commissioning of the PPIS. Commissioning includes downloading and testing the device configuration, checking instrument transformer connections, testing UPS function, and confirming dial-up connection and downloading of data.

10.5 Apparatus Commissioning Requirements

Commissioning of station apparatus equipment shall be performed in accordance with the Canadian Electrical Association's "Commissioning Guide for Electric Apparatus" or equivalent. Commissioning shall include but not limited to:

- Power factor tests of high voltage equipment at 10 kV to ensure insulation adequacy,
- Timing and resistance tests of main and/or generator circuit breaker(s),
- Integrity checks of auxiliary switches, and
- Continuity checks on control, power and protection cabling to equipment.

10.6 Transmission Line

Prior to receiving approval from BC Hydro for connection to the BC Hydro facilities, the transmission line must meet the following requirements:

a) Approval by the Electrical Inspector or the authority having jurisdiction;

b) Assurance by the named registered Professional Engineer of record that the constructed transmission line complies with the design;

c) Test reports submitted to BC Hydro:

   (i) T/L structure ground resistance for applicable structures

(ii) Phasing check;

10.7 Special Factory and Commissioning Tests for Wind Turbine Generators

The following tests are required for the applicable type of WTGs:

- The voltage ride-through capability for each type of turbine control;
- Voltage regulation and reactive power response by demonstrating the ability to control POI voltage within full reactive power capability;
- Reactive power control and the ability to provide continuous reactive power;
- Availability of continuous reactive power over the range of voltage and frequency;
- That measured harmonics are within acceptable levels;
- That measured voltage flicker is within acceptable levels;
- The coordination between WGF protection equipment and the transmission system. This may be done by simulation;
- Power ramping and power curtailment ;
- Availability of SCADA and meteorological data specific to WGF; and
- Any other tests required by BC Hydro.

If the WTG behaviour does not conform to the model, the WGF proponent is responsible for any additional costs for interconnection to the Transmission System.

11. Maintenance Requirements

11.1 General

The GO has full responsibility for the maintenance of its transmission lines, rights of way vegetation clearing, stations, protection, and telecommunications equipment, up to the POI, consistent with the SGIA. General maintenance requirements include:

- Maintenance work shall be done by competent personnel,
- The GO shall maintain equipment used to control, generate, protect, and transmit electricity to the Transmission System, and perform vegetation management all in accordance with applicable reliability standards to ensure that the reliability of the Transmission System is not adversely affected.

BC Hydro reserves the right to request the GO to inspect and test their equipment where there is concern that the GO's facilities are impacting BC Hydro facilities. BC Hydro may order the suspension of the transmission voltage interconnection if the GO's maintenance negatively impacts the reliability of the BC Hydro System, or if BC Hydro is made aware of a safety hazard related to the GO's Facilities.

11.2 Scheduled Outages Requirements

GO shall coordinate planned outages for maintenance on GO's equipment with the BC Hydro Control Centre. The Control Centres shall coordinate planned outages for maintenance and/or modification on BC Hydro facilities with the GO. Planned outages should not impair the safe and reliable operation of the Transmission System.

11.3 Preventive Maintenance Requirements

The GO shall have a preventive maintenance program and retain maintenance records for audit purposes in compliance with applicable standards imposed by NERC/WECC or a reliability organization having jurisdiction in BC. Maintenance will be based on time or on other factors, including performance levels or reliability, and shall follow the manufacturers' recommendations and/or accepted electric utility preventive maintenance practices.

11.4 Protection and Telecommunications Equipment

Periodic maintenance of protection equipment shall include, but not limited to, the calibration (where applicable) and functional testing of all protective relays, the associated telecommunications equipment, and the trip testing of the corresponding circuit breakers.

The GO is responsible for maintenance of the protection and telecommunications equipment and shall keep records thereof to be available to BC Hydro on request. The GO shall also keep current as-built drawings. It is recommended that this maintenance include calibration testing of the relay and trip testing to the circuit breaker at intervals consistent with the manufacturers' recommendation.

The interval between tests for protective relays and telecommunications equipment shall be in accordance with applicable NERC/WECC requirements and Good Utility Practice.

Facilities shall be available for testing to provide isolation from current transformers, potential transformers, and trip buses and to allow AC injection tests.

11.5 Telecommunications System Sustainment

The GO shall have a telecommunications system sustainment plan to ensure that their telecom and terminal equipment remains online, operates reliably, and is maintained. If the situation arises that any system component can no longer be maintained, potentially following manufacturer discontinuance, lack of spare parts, or maintenance contracts not renewable; then contact your BC Hydro Interconnections Manager.

12. Regulatory and Reliability Requirements

BC Hydro and the Customer shall comply with:

a) the applicable reliability standards approved by the BCUC for application in British Columbia;

b) any applicable criteria, requirements, policies or guidelines of WECC that may apply in British Columbia or the western interconnection;

c) respective NERC operating policies,

GO owned RAS facilities must meet BC, WECC, and NERC MRS requirements.

BC Hydro and the GO's obligations shall be subject to any required approval or certificate from one or more governmental authorities.

Indirect Interconnections

A generator interconnecting on to a private line must have the agreement of the private line owner. A bulk generator addition may also require the private line owner to become registered under the BC Mandatory Reliability Standards *and become responsible for transmission owning, planning and operating requirements*.

13. References

The following list of standards is provided for reference only. It is the responsibility of the GOs to comply with all applicable standards.

13.1 BC Hydro

1T-35 - Commissioning Procedure for Station and Transmission Projects

P.10-2017-001 R03 - Transmission Lines Asset Transfer Policy - Design and Construction Requirements

13.2 CSA

CSA C22.1, C22.2 and C22.3 – Canadian Electric Code Parts I, II & III.

CSA C57-98 (Reaffirmed 2002) Electric Power Connectors for use in Overhead Line Conductors

CSA C83-96(Reaffirmed 2000) Communication and Powerline Hardware

CAN/CSA-C411.1-M89 (reaffirmed 2004) AC Suspension Insulators

CAN/CSA-C411.4-98 (Reaffirmed 2003) Composite Suspension Insulators for Transmission Applications

CAN/CSA-G12-92 (Reaffirmed 2002) Zinc-coated Steel Wire Strand

CAN3-C108.3.1-M84 Limits and Measurement Methods of Electromagnetic Noise from AC Power Systems, 0.15 – 30MHz

13.3 IEEE Standards (www.ieee.org)

IEEE Std C37.1 – Standard Definition, Specification and Analysis of Systems Used for Supervisory Control, Data Acquisition and Automatic Control

IEEE Std C37.2 – Standard Electrical Power System Device Function Numbers

IEEE Std C37.122 – Standard Gas Insulated Substations

IEEE Std. C50.12 – Salient Pole Synchronous Generators

IEEE Std. C50.13 – Cylindrical-Rotor Synchronous Generators

IEEE Std C57.116 – Guide for Transformers Directly Connected to Generators

IEEE Std C62.92.5 – Guide for the Application of Neutral Grounding in Electrical Utility Systems

IEEE Std 80 – Guide for Safety in AC Substation Grounding

IEEE Std 81 – Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System

IEEE Standard C95.6 – 2002 IEEE Standard for Safety Levels with respect to Human Exposure to Electromagnetic Fields 0 to 3 kHz

IEEE Std 100 – The New IEEE Standard Dictionary of Electrical and Electronics Terms (ANSI)

IEEE Std 122 – Recommended Practice for Functional and Performance Characteristics of Control Systems for Steam Turbine-Generator Units

IEEE Std 125 – Recommended Practice for Preparation of Equipment Specifications for Speed Governing of Hydraulic Turbines Intended to Drive Electric Generators

IEEE Std 421-1 – Standard Definitions for Excitation Systems for Synchronous Machines

IEEE Std 421-2 – Guide for the Identification, Testing and Evaluation of the Dynamic Performance of Excitation Control Systems

IEEE Std 421-4 – Guide for the Preparation of Excitation System Specifications

IEEE Std 519 – Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems

IEEE Std 525 – Guide for the Design and Installation of Cable Systems in Substations

IEEE Std 605 – Guide for Design of Substation Rigid-Bus Structures

IEEE Std 979 – Guide for Substation Fire Protection

IEEE Std 1127 – Guide for the Design, Construction and Operation of Electric Power Substations for Community Acceptance and Environmental Compatibility

IEEE Std 2800-2022 – IEEE Standard for Interconnection and Interoperability of Inverter-Based Resources (IBRs) Interconnecting with Associated Transmission Electric Power Systems

13.4 WECC Guidelines (WECC website)

WECC Coordinated Off-Nominal Frequency Load Shedding and Restoration Plan

WECC Under-voltage Load Shedding Guidelines

WECC Generator Test Guide

WECC Wind Power Plant Modeling Guide

WECC Solar Photovoltaic Power Plant Modeling Guide

WECC RMS Agreement to be entered into between the WECC and non-FERC-jurisdictional Transmission Operators within the WECC – Canadian Version

WECC Reliability Criteria

13.5 NERC Standards

NERC Reliability Guideline for Improvements to Interconnection Requirements for BPS-Connected Inverter-Based Resources

NERC Reliability Guideline for Electromagnetic Transient Modeling for BPS-Connected Inverter-Based Resources—Recommended Model Requirements and Verification Practices

13.6 Others

ANSI C84.1 – Voltage Ratings for Electric Power Systems and Equipment (60 Hz)

Note: Ferrous material shall meet Energy Absorption Level 1 per Clause 6.2.4.1

O15-05 Wood Utility Poles and reinforcing Stubs

Appendix A – Power Parameter Information System

A1. General Description

The PPIS monitors and records individual power-line electrical parameters (KW, kVAR, kV, kVA, PF, Hz, Harmonics, Flicker, Transients, Min, Max, Events, Outages, Machine Dynamics, etc.) The PPIS is usually installed at the POI but other suitable locations may be selected with agreement between the GO and BC Hydro.

BC Hydro will provide the PPIS system requirements including approved measurement devices to the GO. The PPIS is supplied, configured and installed by GO.

The PPIS checks the power system performance and provides technical information on electrical system operations in steady and dynamic states and during power outages. This information shall be made available to both the GO and remotely to BC Hydro technical personnel.

A2. Power Parameter Information System Requirements

The PPIS consists of a multi-profile power meter with local display connected to protection grade voltage transformers (VT, 120V secondary) and current transformers (CT, 5A secondary) with FT-1 type test blocks. Use of CVTs may require the addition of ancillary harmonic measuring capabilities.

The PPIS system is preferably installed indoors with front facing local display, but it may be outdoors if more convenient. Power to the meter should be supplied from the 125VDC station battery or 120VAC with a UPS to ensure a minimum of 4 hours of PPIS operation during a power outage

The GO will supply an IP connection for remote interrogation by BC Hydro's Power Quality software. Examples of communications media include cellular, satellite, and Internet VPN. In the absence of commercial communications providers, direct connection to BC Hydro communications facilities (if present at the GO) may be possible. All communications are subject to BC Hydro review and approval.

A3. Commissioning

The PPIS system shall be commissioned by the GO prior to generator operation. It shall be checked and tested correct wiring, phasing, voltage, and current levels as well as functional tests for local and remote access by BC Hydro. The commissioning report will be made available to BC Hydro. The PPIS configuration, programming, settings, are to be done by the GO. BC Hydro may assist with providing the configuration requirements.

A4. Operation and Maintenance

The GO is responsible for the maintenance of all PPIS components including the communications equipment. BC Hydro will periodically connect to the PPIS meter to download the captured information. This system requires very low maintenance. However, BC Hydro may require access to the system for onsite inspection, testing and calibration purposes.

Appendix B – Data Requirements

The following outlines data that will be required at various stages of planning, design, commissioning, and in-service of the PGF. This data is required by BC Hydro to ensure suitable steps are taken to interconnect the PGF to the Transmission System.

B1 Submission Requirements

B1.1 Format

Wherever possible, all documents shall be provided in both paper and electronic forms.

The preferred format for reports and other documents is Portable Document Format (PDF) and Word for Microsoft Office; for data, drawing indexes and the like is Excel for Microsoft Office.

The preferred formats for drawings are Portable Document Format (PDF).

Unless legibility is a problem, all drawings shall be submitted on either, 'A'-size (8.5" x 11"; 21.6cm x 27.9cm), or 'B'-size, sheets (11" x 17"; 27.9 cm x 43.2 cm).

All data shall be submitted using the Generator Interconnection Data Form (GIDF), which is located on the BC Hydro website. The GO shall provide one copy, signed and sealed by a Professional Engineer registered in the Province of British Columbia, along with an electronic copy in Excel format.

All drawings, maps, data curves or other material requested within the GIDF shall be provided as electronic copy, supplemented with a paper copy if necessary.

B1.2 Typical Information and Data for GO Interconnection Studies

B1.2.1 Connection Location

Location information required will vary depending upon the proposal.

Locations of new substations, generators or new taps on existing lines shall include county, township, range, elevation, latitude, and longitude. BC Hydro also requires driving directions to the location for a site evaluation. The information shall:

- Identify the substation if connecting to an existing BC Hydro substation.
- If the connection is between two existing substations, identify both substations.
- For connection to an existing BC Hydro transmission line, identify the line by name as well as the location of the proposed interconnection.
- If the request includes a new substation or generator site, identify the proposed location.

B.1.2.2 Electrical Data

The electrical data required will depend upon the type of connection requested.

1. **Electrical One-Line Diagram**

   The electrical one-line diagram should include equipment ratings, equipment connections, transformer configuration, generator configuration and grounding, bus, circuit breaker and disconnect switch arrangements, etc.

2. **Generator Data**

   If different types of generators are included, data for each different type of generator and generator step up transformer shall be provided in addition to the following data:

   2.1 Generator General Specifications

   Energy source (e.g., natural gas, coal, wind, solar, BESS, hydro, co-generation, geothermal, etc.).

   Number of rotating generators and power inverters (for IBRs).

   Number of turbines, combustion, steam, wind, hydro, etc.

   Total project output, MW (@ 0.90 PF for synchronous generators).

   Station service for plant auxiliaries, KW, kVAR.

   Station service connection plan.

   2.2 Generator Data, Synchronous Machines

   Data for each different rotating-machine generator assembly generator, turbine, and shaft shall be provided. Also, GO shall provide the graphs and parameters for each type and size of specified generator as supporting technical documentation identifying the following information:

- Reactive capability, 'P-Q' curves
- Excitation 'Vee' curves
- Saturation and synchronous impedance curves
- Identifier (e.g., GTG #12)
- Number of similar generators
- Complex power, kVA
- Active power, KW
- Terminal voltage, kV
- Machine parameters

  a. Sb – Complex power base (MVA) upon which machine data is specified *b.* H – Normalized rotational kinetic energy of the generator/turbine/shaft assembly, KW-sec/kVA

c. WR2 – Moment of inertia, kg m^2

d. Ra – Armature resistance, pu

e. Xd – Direct axis unsaturated synchronous reactance, pu

f. X'd – Direct axis unsaturated transient reactance, pu

g. X'q – Quadrature axis saturated and unsaturated transient reactance, pu

h. X"d – Direct axis saturated and unsaturated sub-transient reactance, pu

i. Xl – Stator leakage reactance, pu

j. X2 – Negative-sequence reactance, pu

k. X0 – Zero-sequence reactance, pu

l. Xn – Zero-sequence unit grounding reactance, pu

m. Rn – Zero-sequence unit grounding resistance, pu

n. T'do – Direct axis transient open circuit time constant, seconds

o. T'qo – Quadrature axis transient open circuit time constant, seconds

p. T"do – Direct axis sub-transient open circuit time constant, seconds

q. T"qo – Quadrature axis sub-transient open circuit time constant, seconds

r. S(1.0) – Saturation factor at rated terminal voltage, A/A

r S(1.2) – Saturation factor at 1.2 per unit of rated terminal voltage, A/A

Excitation system modeling information

a. Type (static, ac rotating, etc.)

b. Maximum/Minimum DC current

c. Maximum/Minimum DC voltage

d. Nameplate information

e. Block diagram

f. Power System Stabilizer (PSS) type and characteristics

Speed governor information with detailed modeling information for each type of turbine.

a. Turbine type (Combustion, Steam, Wind, Hydro)

b. Total capability, MW (available peak operation rating)

c. Number of stages

d. Manufacturer and model, if known

e. Frequency vs. time operational limits, seconds at Hz

f. Maximum turbine ramping rates, MW/minute, ramp up and ramp down

e. Block diagram

2.3 Generator Data, Inverter-based Resources

As stated in Section 4, the Generator Interconnection Data Form (GIDF) requests the IBR generator data, the collector system information, electrical parameters, and modeling information of generating facilities together with other information for the PGFs.

A few key steady state data for the IBRs are highlighted below:

• Number and nameplate rating of wind turbines or static conversion devices (e.g. inverters for solar PV and BESS)

• DC Sources: If the generator project includes DC sources such as fuel cells, batteries, or photovoltaic devices, provide the number of DC sources and maximum dc power production per source in kW. Provide the nameplate output rating of each inverter in KW and power factor.

• Inverter Loading Ratio for solar photovoltaic projects (ratio of DC panel capability to AC inverter output capability)

for the IBRs with BESS:

• Specification of capability to charge from the AC grid (yes/no)

• Specification of whether AC stand alone or DC connection (relevant for hybrid facilities or BPPs)

• Number of supervisory controllers to be installed

• Specification of common plant-level voltage controller of all assets (e.g. solar, wind, and batteries), especially for HPPs with BESS

o If no common plant-level controller, a description of the asset coordination.

In addition to the steady state data, the GO shall supply data and one or more detailed models of the IBRs required to conduct dynamic simulation studies. The GO shall supply a demonstration of the conformity of the dynamic models with the real behavior of the generating station.

2.4 Generator Data, Other Asynchronous Machines

Shunt reactive devices (capacitor banks) for power factor correction with induction generators or converters.

a. PF without compensation

b. PF with full compensation

c. Reactive power of total internal shunt compensation voltage, kVAR

AC/DC Converter devices employed with certain types of induction motor installations or with DC sources.

a. Number of converters

b. Nominal AC voltage, kV

c. Capability to supply or absorb reactive power, kVAR

d. Converter manufacturer, model name, number, version *e.* Rated/Limitation on fault current contribution, kA

Machine parameters

a. Sb – Complex power base (MVA) upon which machine data is specified

b. H – Normalized rotational kinetic energy of the generator/turbine/shaft assembly, seconds

c. Rated terminal voltage, kV line-to-line

d. Rated armature current kA

e. Power factor at rated load

f. Efficiency at rated load

g. Slip at full load

h. Starting current at rated voltage

i. Starting torque at full voltage divided by full load torque

j. Maximum torque divided by full load torque

k. Number of poles

l. Polar moment of inertia (kg m2), alternatively, the time to reach rated speed when full load torque is applied, seconds.

External Shunt Compensation

a. Bus Voltage

b. Number and rating of each shunt capacitor section

c. Voltage/PF controller scheme description and time delays

3. Transformer Data

The following data shall be provided for each unique transformer:

Transformer number or identifier

Number of similar transformers

Transformer type and number of windings, (e.g. Autotransformer, two winding)

Transformer winding data. For a two winding transformer, only winding H and X data is required.

a. For each winding, H, X, y:

1) Nominal voltage, kV

2) Configuration (Δ or Y) and Y winding connection (ungrounded, solid ground or impedance ground)

b. Transformer MVA ratings:

1) Winding H to X, MVA

2) Winding H to Y, MVA

3) Winding X to Y, MVA

c. Transformer impedances, positive and zero sequence:

1) Winding H to X, % X and R at MVA

2) Winding H to Y, % X and R at MVA

3) Winding X to Y, % X and R at MVA

d. Transformer tap changer information

1) No load or load
2) Tap changer winding location, H, X, Y
3) Available taps

e. Transformer cooling requirements if required from BC Hydro

1) Load, amps
2) Voltage, single or three phase, kV

4. Transmission Line Data

If a new transmission line is to be included as part of the proposed connection, the following transmission line data shall be provided:

a. Nominal operating voltage, kV

b. Line length, KM

c. Line capacity, amps at ºC

d. Overhead/underground construction

e. Positive and zero sequence transmission line characteristics in primary values

1) Series resistance, R Ω
2) Series reactance, X Ω
3) Shunt susceptance, B μ S (or μ Ω –1)

B1.3 EMTP Data

A proven EMTP (electromagnetic transients program), specifically PSCAD/EMTDC or EMTP-RV, model of each proposed IBR type, the collector network, and any static or dynamic VAR compensating components (i.e., Statcoms, SVCs, D-VARs) shall be provided to BC Hydro for Interconnection Impact Studies. The dynamic components shall be modelled such that is representative of the full dynamic response capability of that component (i.e., the component model shall provide the correct dynamic range and output as intended by the manufacturer's design). Failure to supply a PSCAD or EMTP-RV model will force BC Hydro to take a more conservative approach to the design and may result in a significant additional cost to the proponent. More detailed requirements of the model are provided in the following subsections.

The model can optionally connect at the high voltage level (for example, 230kV) or at the mid-voltage level (for example, 35kV). If the model is black-boxed at the high voltage level, then inputs for transformer impedances, ratings, winding configuration, rated voltages, and tap settings should be available.

The model shall be available to study engineer designated by BC Hydro, whether this is the utility, consultant, or manufacturer (with the understanding that a Non Disclosure Agreement may be required). The model is not intended to be made "public".

The following data is required for synchronous generators:

- Vterm (rated terminal voltage upon which the pu system is based)
- Srated (rated MVA of the machine upon which the pu system is based)
- Ra (armature resistance) in pu
- Xl (armature leakage reactance) in pu
- Xd (unsaturated direct-axis synchronous reactance) in pu
- Xq (unsaturated quadrature-axis synchronous reactance) in pu
- X'd (unsaturated direct-axis transient reactance) in pu
- X'q (unsaturated quadrature-axis transient reactance) in pu
- X"d (unsaturated direct-axis sub-transient reactance) in pu
- X"q (unsaturated quadrature-axis sub-transient reactance) in pu
- T'd0 (direct-axis open circuit transient time constant) in seconds
- T'q0 (quadrature-axis open circuit transient time constant) in seconds
- T"d0 (direct-axis open circuit sub-transient time constant) in seconds
- T"q0 (quadrature-axis open circuit sub-transient time constant) in seconds
- Rneutral (the neutral part of the neutral grounding impedance) in pu
- Xneutral (the imaginary part of the neutral grounding impedance) in pu
- Xc (Canay reactance) in pu
- H constants in MW-s/MVA or else J moment of inertia (WR**2) in kg*m**2

For thermal turbine-generator units rated larger than 100 MVA, in addition to the above the following mechanical data shall be provided so that a multi-mass (spring-mass-dashpot) mechanical model can be constructed:

- Number of lumped rotating masses on the turbine generator shaft
- Moment of inertia (lb.-mass ft2) of each lumped mass
- The fraction of the total external mechanical torque of which is applied to the particular mass under consideration
- The spring constant [(million pound-ft)/radians] of the shaft section between the present mass and the next one on the shaft
- The speed deviation self damping coefficient for the mass under consideration
- The mutual damping coefficient pertaining to the present mass with the next mass on the shaft

For Inverter-based resources, the following detailed model data is required:

- Fast inner control loops of the inverters, as implemented in the real equipment and capability of reproducing short-circuit fault current contribution.

- Pertinent control features, such as voltage controllers, phase-locked loops (PLLs), ride-through controllers, sub synchronous control interactions (SSCI) damping controllers.
- Power plant controller (PPC) accurately representing short-term performance, specific measurement methods, communication time delays, transitions into and out of ride-through modes, settable control parameters or options, and any other specific implementation details.
- Pertinent electrical configurations such as filters, specialized transformers, etc.
- Pertinent mechanical configurations such as gearboxes, inertia of blades, pitch controllers, etc (for WGF).
- Pertinent detailed protections for both balanced and unbalanced fault conditions, such as overvoltage, undervoltage protections (individual phase and RMS), frequency protections, DC bus voltage protections, converter overcurrent protections, and any other inverter specific protection.
- Dynamic reactive devices including automatically controlled capacitor and reactor banks if applicable.
- A correctly functioning PSCAD or EMTP-RV case including the IBR model connected to a simple AC system.
- The model must be capable of representing a single unit and should be adaptable to represent any reasonable number of identical units with a minimum of effort.
- It must be possible to run a simulation with a case containing more than one EMT Tool model, where, for example, one model might represent a cluster of IBRs connected to one branch of an IBR.
- Documentation to explain the assumptions and basic operation of what is being modelled as well as a user manual.
- Model validation documents comparing the EMT Tool model response to real system measurements.

Specific requirements if the EMT Tool is EMTP-RV

The model should participate in the load-flow solution.

The model should flat start in time-domain from the load-flow condition. The power deviation for both active and reactive powers, during the flat-start initialization should be not more than 0.15 per unit of the generator nominal power.

Specific requirements if the EMT Tool is PSCAD

The model should be available in the latest version of PSCAD and should support Inter Visual Fortran Compiler XE versions 12 and 15.

The model should support the “snapshot” feature in PSCAD to allow the simulation to be saved and restarted at any point in time.

Non-essential Requirements IBR models:

- Switching-based model (for doubly fed, SVC and converter based models) for harmonic/power quality studies must be provided.

- "Blackbox" models are acceptable, provided the following inputs/outputs are available:

  Inputs (minimum):

  - Scaling factor to represent N lumped machines
  - Power input (pu)
  - Control mode (local voltage control, reactive power control, and external control)
  - Any additional external settings which may need to be modified (i.e. voltage control gains, etc.)
  - Compounding impedance (pu) for voltage controller
  - Protection settings which may need to be modified (i.e. ride-through, under-voltage, r over-voltage, under-frequency, over-frequency, etc.);
  - External control input of the high side breaker (if the high side breaker is included in the blackbox model)
  - Wind gust input for WGF
  - Others (model #, presence of optional control/hardware operational features)

  Outputs (minimum):

  - Trip indication (also indicates which protection operated)
  - Measured RMS voltage (pu), real and reactive output power

In addition to the requirement that an EMT Tool model of the IBR be provided, the following additional information should be provided:

- Harmonic and flicker data
- Graphs of reactive power versus voltage
- Protection diagrams and settings

B2. Generating Unit Testing and Model Verification

B2.1 Generating Facility Data and Model Verification

The GO shall provide to BC Hydro the unit testing information in modeling verification reports for the PGF as specified in relevant NERC standards such as MOD-025, MOD-026 and MOD-027 and augmented with the WECC guideline "***WECC Generating Facility, Testing and Model Validation Requirements*** [7]". Specifically, the GO shall review, verify and update the PGF data when any of the following conditions occur:

- No later than 365 days after the new Generating Facility is released for Commercial Operation.

[7] "***WECC Generating Facility, Testing and Model Validation Requirements***" and *Generating Unit Baseline Test Requirements document* can be found at www.wecc.biz.

- Provide revised model data or plans to perform model verification for an applicable unit or plant to its Transmission Planner within 180 calendar days of making changes to the excitation control system or plant volt/var control function or making changes to the turbine/governor and load control or active power/frequency control system that alter the equipment response characteristic.
- Periodic verifications and submissions as required by the applicable standards.

B2.2 Generator Outage Data

The GO is expected to submit generator outage data within 15 days of the end of each month to the CEA and to NERC.

The reporting procedure as described in BC Hydro System Operating Order 1P-14 (Generation Equipment – Status Reporting) is based on a method developed by the CEA of assigning "states" to the operation of a unit. Prior to full commercial in-service, BC Hydro will supply the GO with a copy of such order.

Alternatively, the GO can make separate arrangement with BC Hydro for a joint submission.