60 kV to 500 kV

Technical Interconnection Requirements

For

Power Generators

Revision: 1.4

Effective Date: June 02, 2014

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Chief Planning Engineer

Disclaimer

This document is not intended as a design specification or as an instruction manual for the Power Generating Facility (PGF) connecting to the BC Hydro System and shall not be used by the Power Generating Facility proponent for those purposes. Persons using the information included in this document shall do so at no risk to BC Hydro, and they rely solely upon themselves to ensure that their use of all or any part of this document is appropriate in the particular circumstances.

The proponent, its employees or agents must recognize that they are, at all times, solely responsible for their PGF design, construction and operation. Neither BC Hydro nor any of its employees or agents shall be, nor become, the agents of the proponent in any manner whatsoever arising.

BC Hydro's review of the specifications and detailed plans shall not be construed as confirming or endorsing the design or as warranting the safety, durability or reliability of the PGF. BC Hydro, by reason of such review or lack of review, shall be responsible for neither the strength, adequacy of design or capacity of equipment built pursuant to such specifications, nor shall BC Hydro, or any of its employees or agents, be responsible for any injury to the public or workers resulting from the failure of the PGF.

In general, the advice by BC Hydro, any of its employees or agents, that the PGF design or equipment meet certain limited requirements of BC Hydro does not mean, expressly or by implication, that all or any of the requirements of the law or other good engineering practices have been met by the proponent in its PGF, and such judgement shall not be construed by the proponent and others as an endorsement of the design or as a warranty, by BC Hydro, or any of its employees.

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

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1. Introduction

BC Hydro (BCH) has prepared this **60 kV to 500 kV Technical Interconnection Requirements for Power Generators** (the "TIR") to identify technical requirements for connecting Power Generating Facilities (PGFs) to the BC Hydro System. The purpose of these requirements is to assure the safe operation, integrity and reliability of the BC Hydro System. Contractual matters, such as costs, ownership, scheduling, and billing are not the focus of this document. Transmission Services are not addressed by this document either. All requests for transmission services shall be made independent of the interconnection requests pursuant to the terms of BC Hydro's Open Access Transmission Tariff (OATT). Please refer to the BC Hydro web site, **http://transmission.bchydro.com/** for more information on the interconnection process, business practices, contractual matters and transmission services.

This document is not a design specification or an instruction manual and the information presented is expected to change periodically based on industry events and evolving standards. Technical requirements stated herein are consistent with BC Hydro's current practices for system additions and modifications. These requirements are generally consistent with principles and practices of the North American Electric Reliability Corporation (NERC), Western Electric Coordinating Council (WECC), Northwest Power Pool (NWPP), Canadian Standards Association (CSA), Institute of Electrical and Electronics Engineers (IEEE), American National Standards Institute (ANSI), International Electrotechnical Commission (IEC), and Good Utility Practice. Standards of the above listed organizations and practices are also subject to change.

The Power Generator proponent (PG) 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 PG shall notify BC Hydro immediately in the event of any modifications to the detailed plans that could impact the performance of the interconnection.

The PG 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 PG will communicate directly with all regulatory and governmental authorities in order to ensure that the Power Generating Facility (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 resource plans ahead of time, maintains load-interchange-generation balance within its balancing authority area, and supports interconnection frequency in real time.

BC Hydro (BCH) – BC Hydro is a commercial Crown corporation owned by the Province of British Columbia having its head office at 333 Dunsmuir Street, Vancouver, British Columbia V6B 5R3.

BC Hydro System or Transmission System – the transmission system, protection, control and telecommunications facilities:

- Owned, operated and maintained by BC Hydro

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 Commission'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.

Control Centres (Fraser Valley Office [FVO] and South Interior Office [SIO]) – BC Hydro operates a Primary (FVO) and a Backup (SIO) control centre that are functionally identical and are locations from which BC Hydro operates its Transmission System. FVO and SIO also operates the BC Hydro distribution system and generation system. BC Hydro is responsible for meeting all Balancing Authority (**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 PG 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.

Good Utility Practice – 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.

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

Maximum Power Injection (MPI) – this is the power in MW that can be injected into the transmission system at the Point of Interconnection.

North American Electric Reliability Corporation (NERC) – the North American Electric Reliability Corporation's mission is to ensure the reliability of the bulk power system in North America. To achieve that, 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 users 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) – this is 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.

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

Power Generating Facility (PGF) – a plant/site where generating and related transmission system, protection, control and telecommunications facilities are installed, which is connected to and in synchronism with other generators connected to the Transmission System for the purpose of producing electricity.

Power Generator (PG) – an entity who is a proponent of or an owner of a Power Generating Facility. The PG may consume all or some of the electric energy produced at the Power Generating Facility.

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

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

Standard Generator Interconnection Agreement (SGIA) – a legal document stating the contractual obligations of the PG and BC Hydro. The document covers, but is not limited to, issues relating to facility ownership, operation, dispute mechanisms, and technical requirements. The Interconnection Requirements are incorporated in the SGIA.

Transmission – lines operate at voltages 60 kV and above.

Wind Generating Facility (WGF) - A WGF is defined as 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.

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 or modified interconnections to the BC Hydro System, which is an AC system. Where a PG uses HVDC technology to transfer the PG's power to the POI, it is the PG'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. Specific requirements for Wind Generating Facilities (WGF) interconnection are included in the Appendix A – Wind Generation Interconnection Requirements.

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 Power Generating Facilities (PGF). This document provides information on the interconnection requirements for use by Power Generator proponents (PGs) that have an interest in interconnecting to the Transmission System and identifies:

- The minimum technical requirements the PG'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 PG'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 British Columbia Utilities Commission (BCUC), the North America Reliability Corporation (NERC), and the Western Electricity Coordinating Council (WECC).

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

The PG 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 PG is responsible for obtaining all regulatory approvals, including environmental assessment approvals, if necessary, for the construction and operation of its facilities.

4. General Requirements

The interconnection of PG'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 PG 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.

Extra High Voltage (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, class 1[1] communications system, and insulation coordination to ensure comparable performance to the existing major transmission system.

4.1 Generator Minimum Size

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 of 125%. 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. PGF when connected to the Transmission System should meet the criterion that:

0.7 times 0n-Line Generation MVA > Open-ended Line Charging MVA

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

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

4.2 Safety and Isolating Devices

At the Point of Interconnection, an isolating disconnect device shall be installed and shall meet the following requirements:

- It physically and visibly isolates the Transmission System from the PGF.
- It complies with safety and operating procedures of WorkSafeBC.
- It is rated for the voltage and current requirements of the particular application.
- It is gang operated.
- It is operable under all weather conditions in the area.
- It is lockable in both the open and closed positions.
- It is accessible to BC Hydro at all times.
- Its control and operation are governed by the operating agreements between the PG 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 Point of Interconnection (POI) by agreement of BC Hydro and affected parties.

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

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

- For the protection of maintenance personnel when working on de-energized circuits;
- If the connected facilities or BC Hydro equipment presents a hazardous condition; or
- If the connected facilities jeopardize the operation of the BC Hydro System.

4.3 Point of Interconnection Requirements

4.3.1 General Constraints

The connection methods described below are examples of possible connection methods only and are not intended to be a guide to the PG as to which connection method is appropriate to the installation. 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.

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 need to maintain.

The PGF shall be designed for operation at short circuit (fault) levels that take into account 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.

4.3.2 General Configurations

Connection of new facilities into the transmission system generally falls into one of three categories:

a) Connection into an existing 60 kV to 500 kV bulk power substation with (depending on the bus configuration) the existing transmission and new connecting lines each terminated into bays containing one or more breakers.

b) 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 PG.

c) Connection into an existing 60 kV to 230 kV transmission line via a tap

BC Hydro must maintain full operational control of the transmission path. This 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.

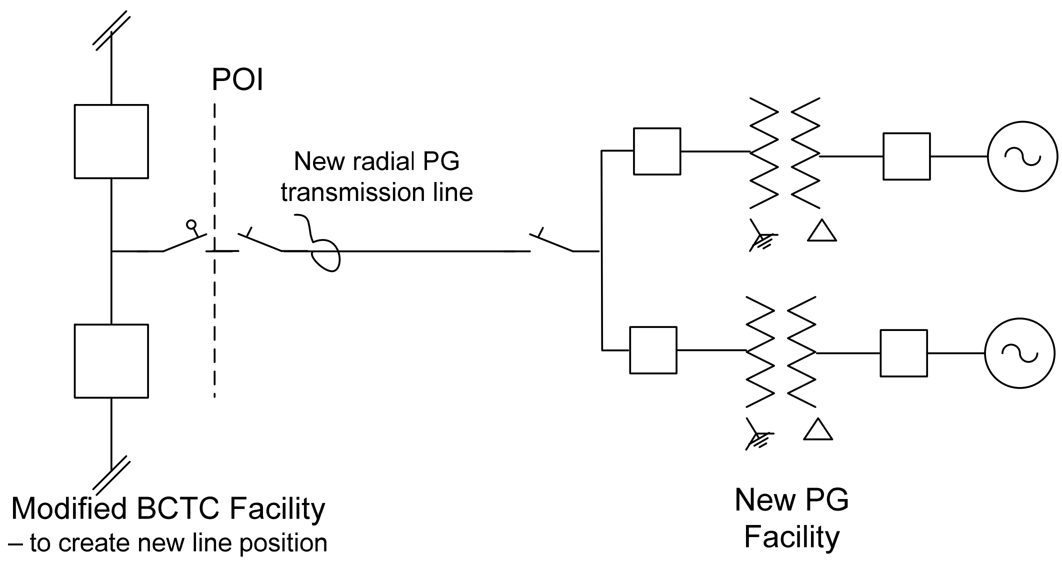
Safety and security rules are in place to prevent un-authorized personnel from having physical access to BC Hydro stations. Design consideration, particularly for protection and control, must include these rules.

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 PG 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

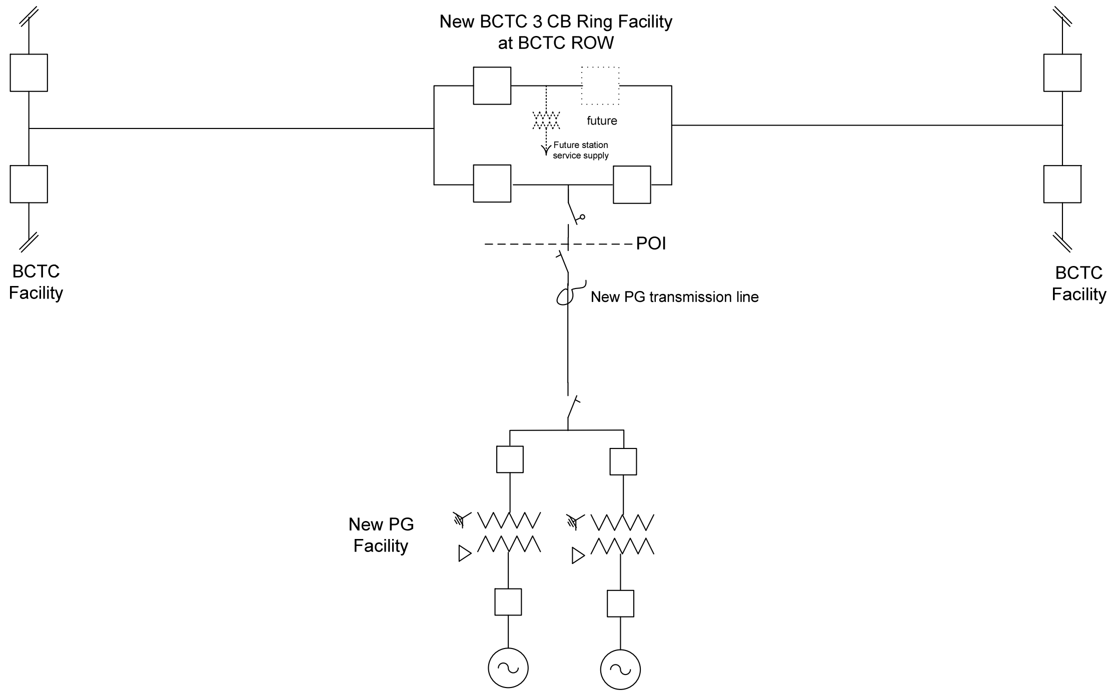
Note: In addition to the Motor Operated Disconnect Switch (MODS) at the BC Hydro station, a ganged disconnect is provided immediately on the PG side of the POI. This allows either party (BC Hydro or PG) to isolate the line without physical access to the other party's facility.

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



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.

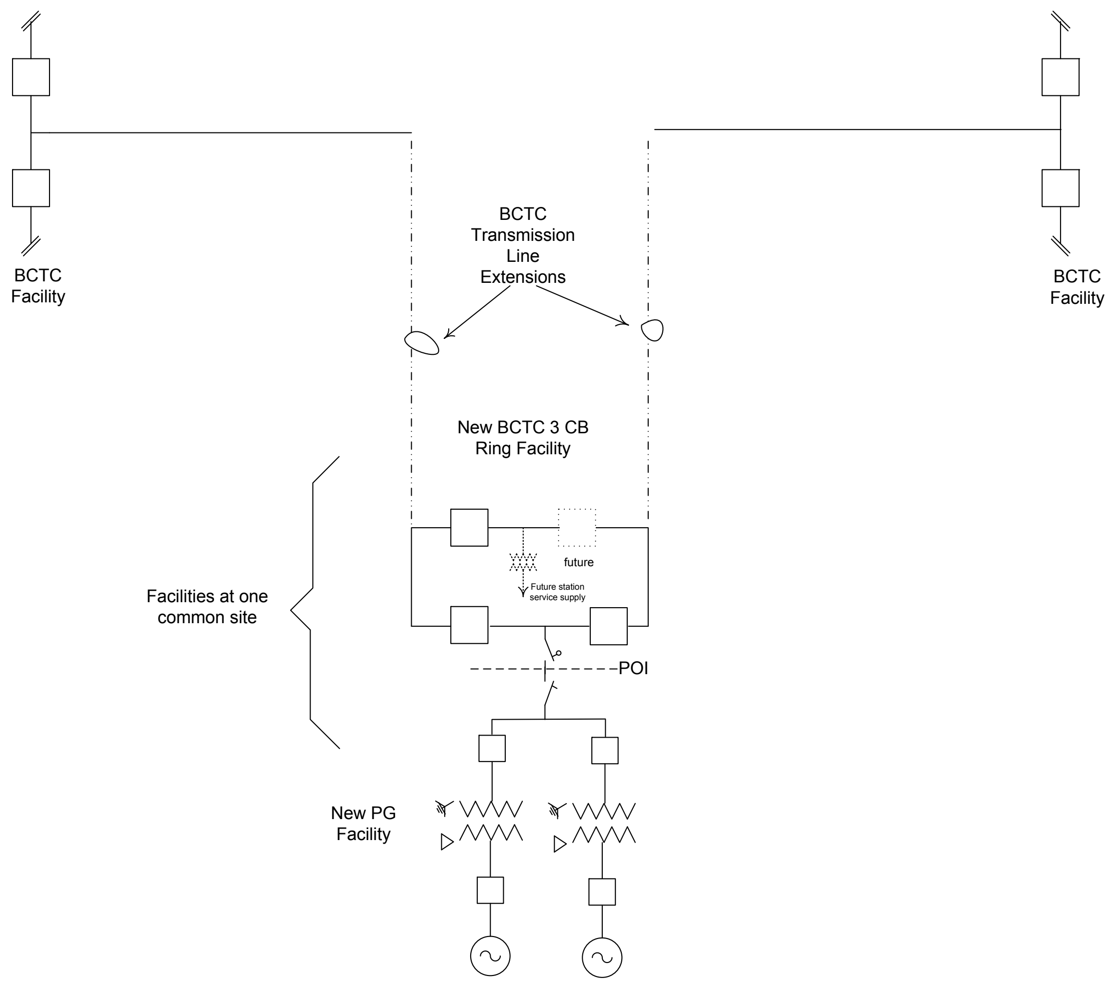
Figure 2: Case (b1) - New BC Hydro Station Connecting Into Existing Transmission Line at ROW



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 PG is brought into a new BC Hydro three breaker ring facility
- The BC Hydro facility is located physically adjacent to the PGF

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

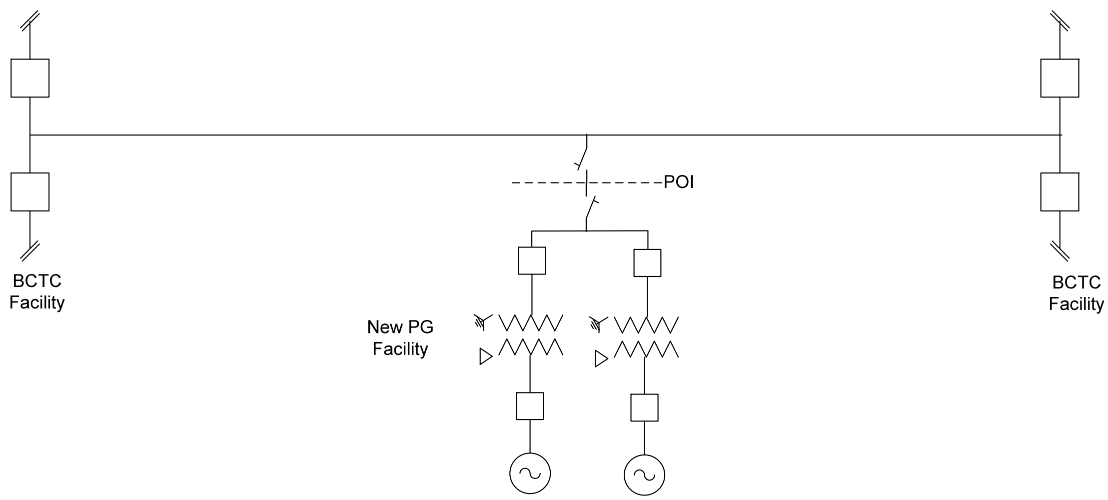


Case (c) is shown in Figure 4 below. Generally, this installation is not desirable because of its negative impact on transmission protection and security.

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) - PG Tapped To BC Hydro Transmission Line



4.3.3 Special Configurations

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

4.4 Transformer Considerations

4.4.1 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. 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 tertiary windings are acceptable for connecting lower voltage collector networks.

4.4.2 Existing Installations

Co-generation 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.

4.5 Other Interconnection Considerations

4.5.1 Existing Equipment

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. Replacement of the impacted equipment or development of alternate plans of service will be part of the interconnections studies.

4.5.2 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 PG should expect to be required to participate in special protection or remedial action schemes (RAS) including automatic generation tripping and load shedding.

4.5.3 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 PG 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. PG selected equipment shall have interfaces compatible with BC Hydro equipment.

BC Hydro will assess whether piloted or non-piloted line protection is required on a case by case basis

4.5.4 Revenue Metering

It is important to incorporate revenue metering early in the design phase of the PGF. Revenue metering equipment shall be installed prior to connecting to the BC Hydro Transmission System, and its location shall be selected and confirmed during the design stage. The revenue metering shall be in accordance with Measurement Canada regulations and, or compatible with, BC Hydro's Requirements for Remotely Read Load Profile Revenue Metering, which is available at http://www.bchydro.com/youraccount/content/forms.jsp. See section 6.2 for possible location.

4.5.5 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.

4.5.6 Atmospheric and Seismic

The effects of windstorms, floods, lightning, elevation, temperature extremes, icing, contamination and earthquakes must be considered in the design and operation of the connected facilities. The PG 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.

4.5.7 Physical Security

The potential vulnerability of the facility to sabotage or terrorist threat should be factored into the design and operating procedures. The PG 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.

4.6 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 through the PG'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.

4.7 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, in order 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 reason, most lines have (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. Furthermore, since BC Hydro line insulation levels are typically higher than line entrance equipment, surge arresters are applied at the line terminals to limit incoming lightning and/or switching over-voltage surges.

4.7.1 Lightning Surges

If the PG 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 5.3.2 for line shielding requirements for lines entering BC Hydro stations.)

4.7.2 Switching Surges

EHV lines and stations rated above 300 kV 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.

4.7.3 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

Nominal Voltage (kV RMS, L-L)	Normal Maximum Voltages (kV RMS, L-L)
60, 66	72.5
132, 138[2]	145
230	253
287	315
360	396
500	550

4.7.4 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

[2] Both 132 and 138 kV are used as the nominal voltage for studies in different locations of the system for historical reasons. Voltages, impedances, and fault levels are stated on the basis of the nominal voltage. Both can be correctly characterized as within the 138 kV voltage class.

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:

- A transformer with the transmission voltage (BC Hydro) side connected in a YG configuration and low-voltage side in a closed Δ.
- A three winding transformer with a closed Δ tertiary winding and both the primary and secondary sides connected YG.
- Installation of a grounding transformer on the high-voltage side.

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.

4.8 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 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 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.

4.9 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. The PG 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. Transmission Maintenance and Inspection Plan (TMIP) requirements are a portion of the WECC Reliability Management System for Transmission. The PG or utility may be required by WECC to annually certify that it has developed, documented, and implemented an adequate TMIP.

4.9.1 Pre-energization Inspection and Testing

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

For equipment that can impact the BC Hydro System, the PG 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 PG 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 PG similar documents describing the BC Hydro POI equipment.

4.10 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 PG. 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.

4.11 Black Start Capability

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

If the PGF is not equipped with the self start capability, the PG 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 5.2.3 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.

4.12 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.

4.13 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.

4.14 PGF Modelling and Data Requirements

The PG shall provide complete models for each component of the PGF. The models and their associated data shall be validated in accordance with Appendix D – Data Requirements.

5. Performance Requirements

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

5.1 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.

5.2 Power Quality

5.2.1 Self Excitation and Resonance Phenomena

The PG 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 PG shall work in consultation with BC Hydro to determine an appropriate solution. BC Hydro will provide the PG with harmonic impedance characteristics at the POI on request.

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

5.2.2 Power Parameter Information System

BC Hydro requires that a Power Parameter Information System (PPIS) to 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 PG staff to assess the condition of electricity generating from the PGF.

See Appendix C – Power Parameter Information System for details.

5.2.3 Voltage Fluctuations and Flicker

Voltage flicker is a momentary increase or decrease in voltage, normally associated with fluctuating load. The characteristics of a particular flicker problem are determined by the nature of the load change. Voltage flicker may arise during the start-up of an induction generator, motor, energization of a transformer, or other equipment where a large inrush of starting current may cause the local system voltage to drop considerably. The PG shall take steps to minimize flicker problems caused by their system.

Specifically, to prevent voltage fluctuations from causing serious disturbances and risks to equipment owned by others that are connected nearby to the Transmission System, the PG shall ensure that:

Phase-to-phase and phase-to-ground 60 Hz root mean square (RMS) voltage change shall not exceed +5% and -6% compared to the immediately preceding one second average value where:

The value, which is compared to the preceding one-second value, is the RMS value calculated over any ½ 60 Hz cycle.

The limits for acceptable voltage fluctuations at the Point of Interconnection are as shown in Table 2:

Table 2: Voltage Fluctuations

Voltage Change	Maximum Rate of Occurrence
+/-3% of normal level	once per hour
+5/-6% of normal level	once per 8-hour work shift
Exceeding +5/-6%	pre-scheduled by BC Hydro

Voltage dips more frequent than once per hour shall be limited to the "Border Line of Visibility Curve" contained in Appendix F (IEEE Standard 519), Permissible Voltage Dips – Border Line of Visibility Curve.

5.2.4 Voltage and Current Harmonics

Harmonics can cause telecommunications interference and thermal heating in transformers; they can harm solid state equipment and create resonant over-voltages. To protect equipment from damage, harmonics shall be managed and mitigated. The PG's equipment shall not cause voltage and current harmonics on the Transmission System to exceed the limits specified in IEEE Standard 519. Harmonic distortion is defined as the ratio of the root mean square (RMS) value of the harmonic to the RMS value of the fundamental voltage or current. Single frequency and total harmonic distortion measurements may be conducted at the POI, the generation site, or other locations on the Transmission System to determine whether the PG's equipment is the source of excessive harmonics.

5.2.5 Phase Unbalance

Unbalanced phase voltages and currents can affect protective relay coordination and cause high neutral currents and thermal overloading of generators and motors. To protect equipment of BC Hydro and third-parties, the PGF's contribution to the total unbalances at the POI shall not cause a voltage unbalance greater than 1% or a current unbalance greater than 5%. Phase unbalance is the percent deviation of one phase from the average of all three phases.

5.3 Station and Switchgear

5.3.1 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.

5.3.2 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 GIS.

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 3 and Table 4 below.

Table 3: 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)	Shielding @ Station Minimum Number of Spans	Shielded Section Line Tower Footing R max (Low Frequency)
69	525	0	
138	860	0	
230	1265	2 (~0.5 km)	10 ohms
287	1345	2 (~0.5 km)	10 ohms
360	1665	2 (~0.5 km)	15 ohms
500	1985	2 (~0.5 km)	20 ohms

Table 4: 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	1300/1300/1175	1050/1050/950	300/288	4	10
500	1550/1550/1550	1175/1175/1175	396/396	5	10

5.3.3 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.

5.3.4 Circuit Breaker Requirements:

All circuit breakers installed at the generation site, the interconnecting substation, the Point of Interconnection, 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 PG assumes the responsibility for upgrading when necessary to accommodate changes to the system. The PG 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.

5.3.5 Circuit Breaker Rated Interrupting Times and Fault Clearing Times

Table 5 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 Point of Interconnection. Expected multi-phase fault clearing times with telecommunications assisted protection are also stated in Table 5.

Table 5: 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 5.

5.4 Generators

The PGF shall comply with codes, standards and rules applicable in BC including NERC/WECC Planning Standards Sections II.B (System Modeling Data Requirements, Generation Equipment) and III.C (System Protection and Control, Generation Protection and Control). The generators shall be designed in accordance with all applicable standards and the following requirements.

5.4.1 Generator Active Power

The active power output should be limited to the lesser of the continuous rating of the prime mover and the generator Rated Power (MVA rating times rated overexcited power factor).

5.4.2 Generator Reactive Power Requirements

- All synchronous generators shall have the ability to operate 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.
- All synchronous generators shall have the ability to operate continuously at their Maximum Power Output (MPO) and at rated field current while at any terminal voltage level within plus 5% and minus 5% of rated terminal voltage.
- All synchronous generators shall have the ability to follow a specified voltage or VAR schedule issued on an hourly, daily, or seasonal basis dependant upon the location of the generator. BC Hydro will specify the desired generator voltage setting or desired MVAR output level for each generator. The generator may be required to change its MVAR output or 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 via supervisory control,

the PG's operator shall be able to implement the new MVAR output or voltage reference set point within an agreed time.

- All synchronous generators shall have the ability to operate for periods of at least 30 seconds at any generator terminal voltage level between 0.70 pu and 1.20 pu with the main circuit breaker open to allow the open circuit saturation test to be conducted, for each generator and its auxiliary equipment.

5.4.3 Generation Excitation Equipment Requirements

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 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 exciter, Automatic Voltage Regulator, Power System Stabilizer and over-excitation limiter shall meet NERC and WECC standards, and the following requirements:

- The high initial response excitation system 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 ("Excitation System Rated Current").
- The excitation system shall be able to provide 1.6 times the excitation system rated current for 30 seconds ("exciter overload current rating").

For 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).

For 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 shall be 2.0 or higher (refer to IEEE Standard 421.1). The exciter ceiling voltage shall be greater than 2 times the rated field voltage.

The PG 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 exciter shall be equipped and operated with an Automatic Voltage Regulator (AVR) set to control the generator terminal voltage. BC Hydro may request connection of the voltage regulator line drop compensation circuit to regulate a virtual location 50-80% through the step-up transformer reactance.

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. The generator and excitation equipment are not required to be capable of continuous operation at these extreme terminal voltage levels.

b) Excitation System Limiter

Excitation limiters shall be coordinated with the generator protective relay settings and shall meet the following requirements:

- Limiter settings shall not restrict the generator's operating range (terminal voltage and MVAR limits) to less than 100% of the continuous capability of the equipment.
- Limiters shall be able to control the exciter output to avoid unnecessary operation of the generator's protective relays in the event of any sudden abnormal system condition.
- Limiters shall be instantaneous reset except for the ones whose designs include modeling of machine thermal characteristics. The output of each limiter shall immediately return to zero when its input returns to zero.
- 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 requirement. The PG shall provide BC Hydro with information on the type and model of PSS for each generator. BC Hydro will conduct studies at the PG's cost to determine the optimum PSS settings that will be implemented and confirmed by field tests during the commissioning of each generator.

5.4.4 Governor Requirements

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;
- Have governor dead-bands shall not exceed +/-0.036 Hz; and

- Be capable of providing immediate and sustained response to abnormal frequency excursions.

5.4.5 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. To ensure that the PG's generator is not tripped prematurely, the required time delay settings for such relays shall not encroach upon the off-nominal frequency described in (a) and the off-nominal voltage limits describe in section (b) below. As well, PGF quality protection (described in section 6.4) shall not encroach upon the operating limits described in (a) and (b) below.

a) Frequency

Each generator shall be capable of continuous operation at 59.5 to 60.5 Hz and of limited time operation at a larger frequency range. If the system frequency declines and governor action is not able to stop the decline, loads are automatically interrupted in discrete steps. This load interruption (load shedding) within the interconnected system is designed to stabilize the system frequency by balancing the amount of generation and load.

Generators shall remain connected to the system during frequency excursions, both to limit the amount of load shedding required and to help the system avoid a complete collapse. Over/under frequency relays are normally installed to protect the generators from operation beyond the safe periods of off-nominal frequency range. BC Hydro will specify the minimum required time. All generators shall meet the minimum criteria listed in Table 6Table 7. During off-nominal frequency excursions, typical hydro generators are expected to have capabilities beyond those listed in Table 6. Where the requirements are not met, PG shall arrange for equivalent load shedding for the corresponding generation tripping.

Table 6: Off-Nominal Frequency Minimum Performance

Under-frequency Limit	Over-frequency Limit	Minimum Time
60.0-59.5 Hz	60.0-60.5 Hz	Continuous
59.4-58.5 Hz	60.6-61.5 Hz	3 minutes
58.4-57.9 Hz	61.6-61.7 Hz	30 seconds
57.8-57.4 Hz		7.5 seconds
57.3-56.9 Hz		45 cycles
56.8-56.5 Hz		7.2 cycles
Less than 56.4 Hz	Greater than 61.7 Hz	0 cycles

Off-nominal frequency requirements are described in detail in WECC document entitled, "WECC Coordinated Off-Nominal Frequency Load Shedding and Restoration Plan."

Generators that participate in "Local Island" conditions as described in section 8.3 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 6.4) must also coordinate with these limits of operation.

b) Voltage

Each generator shall be capable to ride through the disturbances and operate continuously at between 0.90 and 1.10 pu terminal voltage. In certain areas of the Transmission System, under-voltage load shedding protection is used to avoid voltage collapse. The PGF under-voltage relay settings shall have delays that coordinate with the existing under-voltage load shedding program. BC Hydro will specify the minimum required time delays.

The nominal voltage levels available for connecting to Transmission System depend on the location of the PGF. Normal operating voltages on Transmission System can vary by up to +/-10% of nominal voltage levels and may vary over a wider range at certain locations or during abnormal or emergency conditions. BC Hydro will specify the nominal voltage levels.

Table 7 below describes the off-nominal voltage performance limits.

Table 7: Off-Nominal Voltage Minimum Performance

Over-voltage	Under-voltage	Minimum Delay
<1.10 pu	>0.90 pu	Continuous
-	≤0.90 pu	10.0 seconds
≥1.10 pu	-	5.0 seconds
≥1.20 pu	≤0.80 pu	2.0 seconds
≥1.25 pu	≤0.75 pu	0.8 seconds
≥1.30 pu	-	0 seconds

5.4.6 Contingency and RAS Requirements

The PG 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 PG to detect the loss and immediately trip off the affected generators.
- Remedial Action Schemes may be required to mitigate the impacts of contingencies to the Transmission System; e.g., generation shedding, generation run-back, etc.

5.5 Transformer Requirements

The PG 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 4.4 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.

5.6 Transmission Line Design Requirements

Transmission line designs shall meet or exceed the following requirements to ensure no adverse impact on the Transmission System:

- The latest version of CSA Standard CAN/CSA C22.3 No. 1, Overhead Systems

- BC Hydro's Engineering Standards[3] for Overhead Transmission Lines
- BC Hydro's practice for structure design load factors and weather loading factors

The PG shall identify the Professional Engineer of Record responsible for the design.

Although there is no requirement on BC Hydro to take over ownership and operation of a PG 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.

5.6.1 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.

5.6.2 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 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

5.6.3 Line Performance

a) 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 the following:

- Shielding to the transmission line
- Line surge arrestors
- Single-pole reclosing line protection

[3] BC Hydro Engineering "41" Series *Transmission Engineering Technical Standards, Procedures and Guidelines*

Acceptable line performance means similar to line performance to lines constructed for similar purpose in the same voltage class of network transmission lines in the region.

b) 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, line arresters or single-pole reclosing protection shall be applied.

6. Protection Requirements

6.1 General Requirements

6.1.1 Internal Fault Protection

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.

6.1.2 Equipment Rating

The PG's equipment shall be rated to carry, detect and interrupt the present and future fault levels at the PGF. To do this, the PG'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 4.4, and 5.3.4 for further details.)

6.1.3 Unbalance, Under-frequency and Under-voltage

The PG'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.

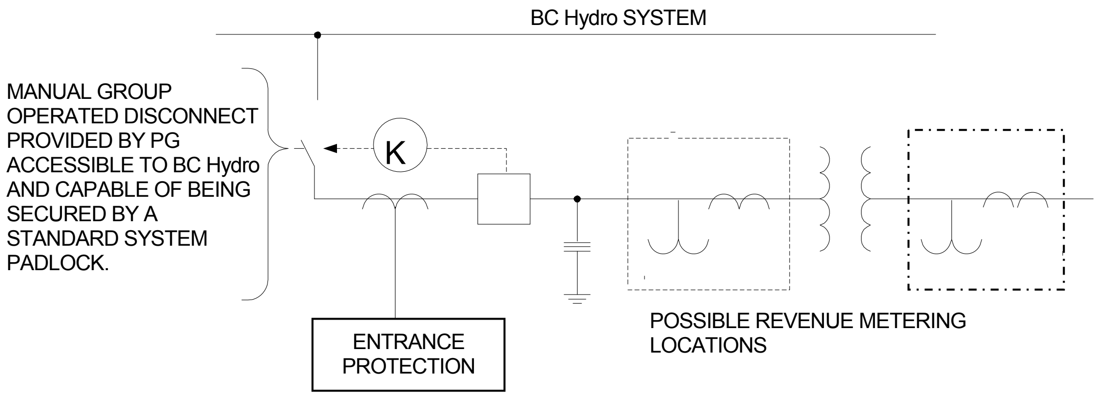
Relays shall be based on solid state or microprocessor technology and shall have a dropout time of 2 cycles or less. The PG shall coordinate their settings with BC Hydro (WECC) requirements.

Under-voltage conditions may occur during emergencies or abnormal operating situations on the Transmission System. The PG is encouraged to use timed under-voltage-tripping (device 27) to protect their equipment. This protection must also be coordinated with the requirements in section 5.4.5.

6.2 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.

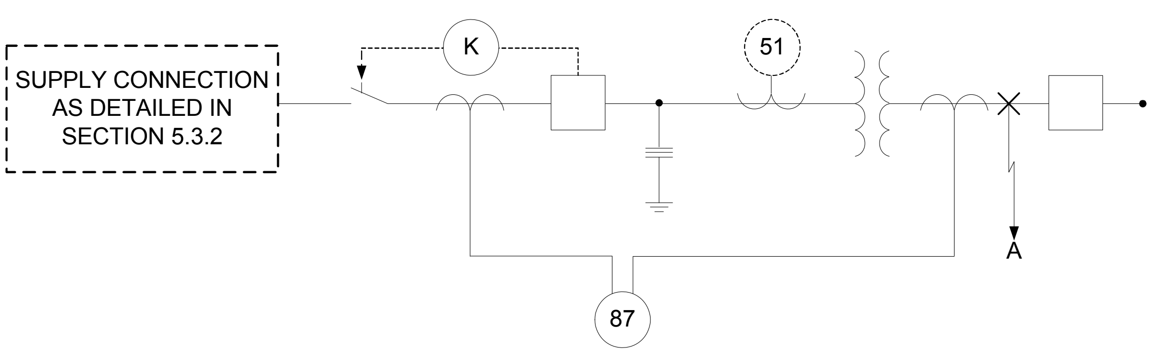
Figure 5: Generic Entrance Protection One-Line Diagram



All PG'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: Entrance Protection Example



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

6.3 Transmission Line Protection Requirements

The PG shall provide redundant equipment to detect all phase and ground faults on the Transmission System. 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.

The PG shall provide additional protection to detect faults on the Transmission System. This protection is generally referred to as "Transmission Line Protection." The required fault clearing times shall be specified by BC Hydro. BC Hydro will recommend the required protection. See also section 4.5.3.

BC Hydro will define the required protection to protect the BC Hydro System.

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

For line protection at the PGF the following shall apply:

- For non-pilot schemes protection, BC Hydro will make recommendations for line protection.
- For pilot schemes, BC Hydro will specify protection schemes.

6.3.1 Detection of Ground Faults

Depending on the PG's transformer winding configuration, possible methods to detect ground faults include:

- For detecting zero sequence voltage in the open Delta secondary of voltage instrument transformers, use a voltage relay (59N), and
- For detecting zero sequence current flow from the PGF to the Transmission System, use a current relay (51N).

6.3.2 Detection of Phase Faults

The PG shall provide dedicated phase fault protection to clear isolated multi-phase faults on the Transmission System using under-voltage relaying (27), directional inverse time over-current relaying (67), impedance relaying (21), or inverse time over-current relaying (51) as appropriate to the installation.

6.3.3 Breaker Failure Protection of the PGF HV Circuit Breaker

Breaker failure protection shall be provided for failure of the main PGF HV circuit breaker failing 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.

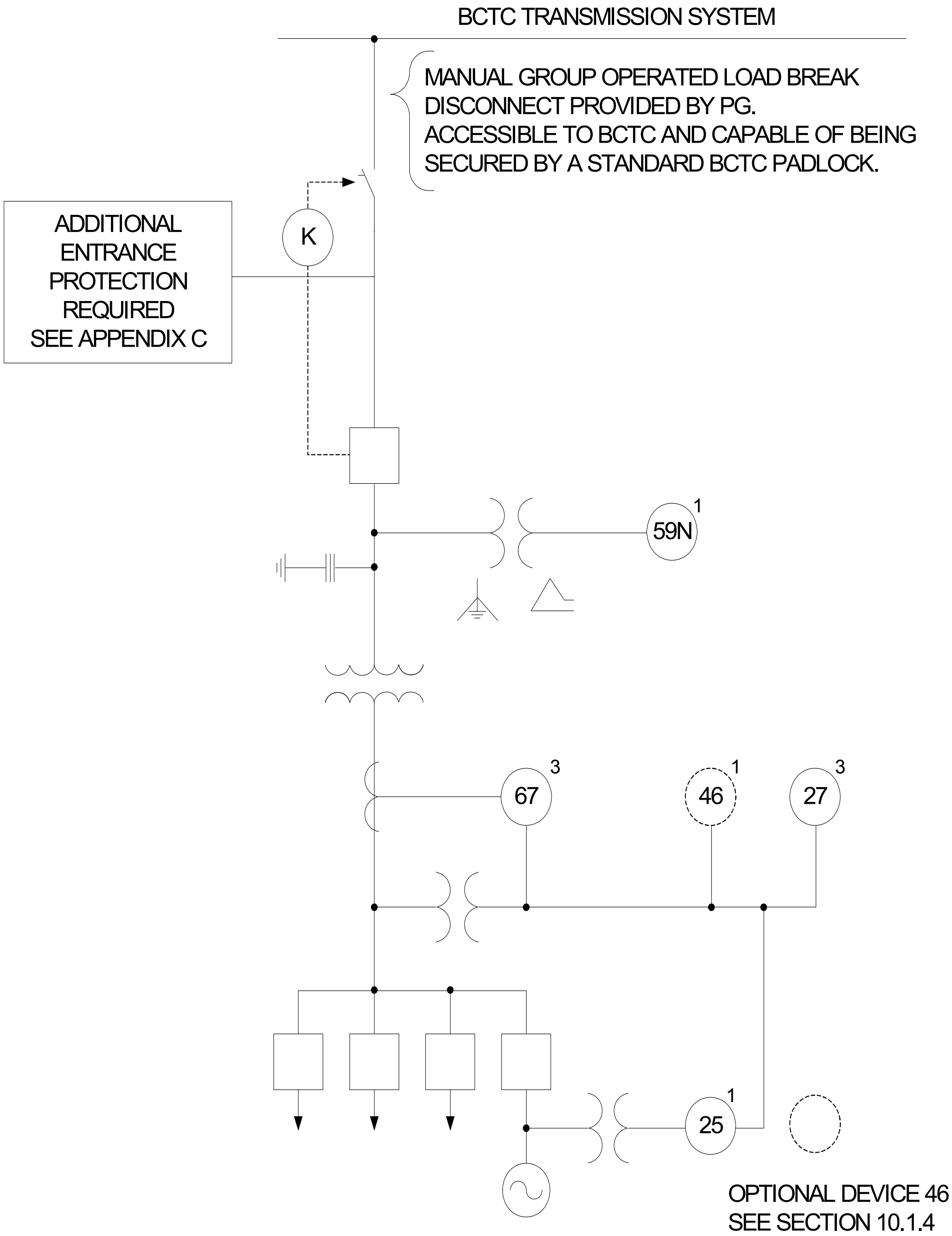
BC Hydro does not intentionally provide breaker failure back-up tripping for the case of the main PGF circuit breaker failing to clear a PGF facility fault. For situations where telecommunications facilities are applied for other reasons (for example transmission line protection), a spare signal channel 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.

6.3.4 Prevention of Energization of Ungrounded Transmission Line by PGF

As indicated in section 4.4.1, 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 PG's transmission line protection is shown in Figure 7 below.

Figure 7: Sample Installation of Minimum Transmission Line Protection



6.4 Power Quality Protection

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

The purpose of power quality protection is to ensure 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 would then possibly meet the requirements of section 5.4.5. If speed of operation is an issue, other measures may need to be taken as described in sections 4.7.3 and 4.7.4.

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 5.4.5.

6.5 Under-frequency Load Shedding Protection

If PGF become connected as a load for any period of time or require 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. (See section 5.4.5 for more details.)

6.5.1 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.

6.6 Batteries / Chargers / DC Supplies

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.

PG 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[4] that:
  - Operates at least 5 VDC above the minimum acceptable voltage to operate the circuit breaker and associated protection and control circuitry,
  - Operates to shut down the generator and open the HV circuit breaker to disconnect the PGF from the Transmission System, and
  - Has delayed trip initiation, not to exceed 1 minute, to override temporary voltage dips.

7. Control and Telecommunications Requirements

7.1 Telecommunications

7.1.1 General

Control and telecommunications facilities, including those for protective relaying and remedial action schemes, 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 7.1.2, 7.1.3 and 7.1.4 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 Supervisory Control and Data Acquisition (SCADA) and other data monitoring systems. BC Hydro may modify its control and telecommunications requirements when detailed PG's equipment information becomes available or changes. All costs to install, maintain and support communication access are the responsibility of the PG.

7.1.2 Telecommunications Media

Telecommunications media alternatives for the PGF may include dedicated or leased metallic wire line circuits, power line carrier, microwave radio, fibre optics, UHF/VHF radio and satellite. When two-way telecommunications media is required, full-duplex (4-wire or equivalent) circuits will generally be used (except for standard voice telephone circuits on wire line, where 2-wire circuits are used).

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

[4] 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.

faults. This equipment is the responsibility of the PG 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.

7.1.3 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 compliance or for contractual obligations
- Equipment for generation shedding or other remedial action scheme 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).

In some cases, a single analog business telephone dial-up line may be used to interrogate the main revenue meter, backup revenue meter, and the PPIS (Power Parameter Information System) equipment. This is achieved by sharing a common telephone line using a balanced telephone line-sharing device.

In order to ensure compatibility of design and operation, BC Hydro will provide technical requirements to the PG 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.

7.1.4 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 remedial actions scheme 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.

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

BC Hydro will not provide High Voltage Telecommunication Entrance Protection equipment.

8. System Operating Requirements

8.1 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.

PG 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 PG will retain final responsibility for the plant.

If the PG's generation is controlled in real time by BC Hydro, the PG shall provide full Supervisory Control and Data Acquisition facilities, including alarm monitoring for each generating unit to a BC Hydro's Control Centre. If the PG's generation schedule is dispatched in real time by BC Hydro, the PG shall provide to a BC Hydro's Control Centre direct control or 24 hour telephone access to a continuously manned PG control centre via a dedicated telephone line. Within an agreed time, the manned PG 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 PG's available generators (synchronization will normally be accomplished using the generator unit breakers),
- Shut down the PG's on-line generators,

- Setup Remedial Action Schemes at the PGF if it is required to participate in generation shedding or run-back,
- Change the output of any of the PG's on-line generators according to an accepted schedule, and
- Change the mode of operation of any of the PG's generators (e.g., from generating to synchronous condenser mode if the units have the capability.)

8.2 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 8.1, 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 PG.

8.3 Generation Islanding

a) 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 5.4.5 and 6.5 for more details.)

Note however a local island could persist as long as PQ and frequency are within acceptable limits.

To protect 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 BC Hydro are required as per Sections6.4 and 6.5. These relays shall not be set with such short time or too narrow an operating window as to encroach on the frequency and voltage limit operating criteria described in section 5.4.5. 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.

b) 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 Remedial Action Scheme 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.

8.4 Normal and Emergency Operations

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

8.5 SCADA, Telecommunications and Control

BC Hydro may require telemetering equipment for readings such as MW, MVAR, MW.h, and kV. Some or all of this data may need to be supplied continuously or via periodic dial-up reporting to BC Hydro Control Centres. The specific requirements will depend on the size of the plant, location, strength of the transmission system at the Point of Interconnection, other generation in the area, and other factors. Telemetry information guidelines are as shown in Table 8, Table 9 and Table 10 below; however the requirements may be increased by Real Time Operations if deemed to have safety or significant operational impacts..

Table 8: Telemetry Data Requirements for Generators up to 10 MVA

Data	Telecommunications (1)
Plant level: MW, MVAR, MW.h (hourly), kV, interconnection status. Line telemetry at POI (if different than plant): MW, MVAR, kV.	Unsolicited report by exception via dial-up RTU with DNP 3.0 protocol; 2-minute maximum to establish connection for BC Hydro interrogation on demand; Reports to a Data Concentration Point (DCP) using; Non-dedicated Telephone analog business line, with entrance protection, provided overall polling interval for all data is less than or equal to 4 seconds, or Stationary Satellite Broadband Link, provided overall polling interval for all data is less than or equal to 4 seconds.

Notes for Tables 8, 9 and 10:

The PG will adhere to the following SCADA design procedure;

PG SCADA DESIGN PROCEDURE (Extract From BC Hydro Engineering Standard ES45-P0210)

According to BC Hydro Design Practice DP 45-P0200, the PG is recommended to use a GE IBOX RTU as a minimum for the interface equipment between the PG and the BC Hydro SCADA network. This will de-couple the design and testing of the PG equipment from the BC Hydro Control Centre and allow the control centre to prepare and pre-commission new RTU database with a test IBOX setup by the BC Hydro SCADA designer. The PG SCADA designer shall follow Step 3b but with more Telecommunication options including dial-up, satellite and cellular data. The PG SCADA designer shall discuss at the beginning of the project cycle with the BC Hydro SCADA designer to determine the technical details of the IBOX and submit technical information and IBOX configuration to enable the BC Hydro SCADA designer to complete the design at the Data Concentration Point (DCP) and pre-commission with BC Hydro Control Centre. If the PG belongs to one of the BC Hydro pre-defined PG type with a standardized DNP point list, a sample IBOX Configuration can be requested from the BC Hydro SCADA team for the PG's reference. After the project is in service, BC Hydro SCADA designer will archive the RTU configuration according to BC Hydro Engineering Standards.

<u>Step 3b. External consultant or PG adding a new GE RTU</u>

At the beginning of the project cycle with a minimum of three months before the in service date, send the P&C scope document to the BC Hydro SCADA designer and request the following information needed to set up a new RTU in the BC Hydro system: DNP address, IP address, Data Concentration Point, GE firmware version, GE BOOTROM version and GE Config Pro version. The network address assignment shall be made according to Design Practice DP 45-Q0022. The external consultant shall also request all the RTU drawing numbers from BC Hydro except for the R27 drawing number which will be reserved by the BC Hydro SCADA designer during archiving of the RTU configuration.

The external consultant shall submit to the BC Hydro SCADA designer the station LAN design architecture for review during the conceptual design phase of the project. The external consultant shall consult with the BC Hydro Telecommunications Department to ascertain whether direct RS232 connection or leased line dedicated modem connection will be used for the station involved. Based on that result, the external consultant shall request the BC Hydro SCADA designer to reserve either a direct connect RS232 port or a four wire modem port at the Data Concentration Point.

The external consultant shall prepare a tested version of the RTU Configuration and send to the BC Hydro SCADA designer, together with all RTU drawings, P&C drawings and DNP point lists of all LAN devices, at least ten weeks before the in service date. The BC Hydro SCADA designer will perform pre-commissioning with BC Hydro Control Centre and archive the RTU configuration according to BC Hydro Engineering Standards after the project is in service. The external consultant is responsible for all hardware design, RTU drawings, installation, testing and commissioning.

Table 9: Telemetry Data Requirements for Generators between 10 and 30 MVA

Data	Telecommunications (1)
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	Real-time report by exception using a RTU with DNP 3.0 protocol reporting to a Data Concentration Point (DCP). Single dedicated (always on) telecommunications link, i.e. Telus lease, PLC, fibre optic, microwave, etc., provided overall polling interval for all data is less than or equal to 2 seconds, or Stationary Satellite Broadband Link, provided overall polling interval for all data is less than or equal to 4 seconds.

Table 10: Telemetry Data Requirements for Generators 30 MVA and Above

Data	Telecommunications (1)
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.	Real-time report by exception using a RTU with DNP 3.0 protocol reporting to a Data Concentration Point (DCP). Dedicated (always on) telecommunications link, i.e. Telus lease, PLC, fibre optic, microwave, etc., provided overall polling interval for all data is less than or equal to 2 seconds.

8.6 Other Requirements

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

9. Commissioning Requirements

9.1 General

The PG has full responsibility for the inspection, testing, and calibration of its equipment, up to the Point of Interconnection, consistent with the Interconnection Agreement.

9.1.1 General Commissioning Requirements:

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

- Performance of all commissioning by competent personnel,
- Compliance with the various levels of Declarations of Compatibility and Commission Notice to Energize, as required, defined in Appendix E – Declaration of Compatibility 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 not limited to, generator performance, protective relaying, telecommunications, and revenue metering. Inspection and testing shall confirm the compatibility of the PG's equipment and controls with BC Hydro System where applicable,
- 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.

9.2 Generator Commissioning Requirements

BC Hydro requires the following for the commissioning the PGF or after modifications to the PGF at the PG's costs:

- Testing to confirm generator model data as per WECC's policy "*GENERATING UNIT MODEL VALIDATION POLICY",* which can be accessed from their web site (http://www.wecc.biz/), such that test data be made available within:
    - 180 days of a generator entering Commercial Operation, and
    - 180 days of changes made to an in service generator, which modified equipment, control settings, or software that influences the behaviour of the plant with respect to the Transmission System (e.g. excitation retrofit, additional control function within a controller, turbine

modification, voltage regulator and Power System Stabilizer tuning modification, etc.); only those portions of the generating unit model that can be influenced by the modifications need to be tested and validated. (See Appendix D – Data Requirements for more details.)

- Provision of results of the generating unit testing and model validation to BC Hydro for review and content approval before connecting the PG's generating units to the Transmission System for any purpose other than commissioning and testing, and
- Re-testing of some or all generating units and their models validated periodically at least every five years as may be required by WECC or as required by other reliability authorities having jurisdiction in BC.

9.3 Protection Equipment

Commissioning of protection equipment shall include but not limited to:

- Ratio, phase and polarity testing of current transformers and potential transformers,
- Calibration checks of each protective relay by injecting the appropriate 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 remedial action scheme 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.

9.4 Telecommunications Equipment

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

9.5 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, Power System Stabilizer 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 Power Parameter Information System (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.

9.6 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. Maintenance Requirements

10.1 General

The PG has full responsibility for the maintenance of its equipment, up to the Point of Interconnection, consistent with the Interconnection Agreement. General Maintenance Requirements include:

- Maintenance work shall be done by competent personnel,
- The PG 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 inspect and test the equipment given reasonable notice.

10.2 Scheduled Outages Requirements

PG shall coordinate planned outages for maintenance on PG’s equipment with the BC Hydro Control Centre. Planned outages should not impair the safe and reliable operation of the Transmission System.

10.3 Preventive Maintenance Requirements

The PG 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.

10.4 Protection and Telecommunications Equipment

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

The interval between tests for protective relays and telecommunications equipment shall be in accordance with applicable WECC requirements and Industry Canada regulations.

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

11. Regulatory and Reliability Requirements

BC Hydro and the PG's obligations shall be subject to any required approval or certificate from one or more Governmental Authorities. The BCUC has regulatory oversight of BC Hydro and all agreements between BC Hydro and the PG.

BC Hydro and the PG shall comply with the applicable NERC standards, WECC standards, and reliability standards approved by regulatory organizations having jurisdiction in BC as well as respective NERC Operating Policies, WECC Minimum Operating Reliability Criteria (MORC), and any other WECC guides or policies that apply.

12. References

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

12.1 BC Hydro

- BC Hydro Transmission Line Construction Requirements

12.2 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

12.3 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

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

12.5 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

BC hydro

FOR GENERATIONS

Wind Generation Interconnection Requirements

A Supplement to

The 60 kV to 500 kV Technical Interconnection Requirements for Power Generators

A1. Background

This Appendix A specifies additional requirements for Wind Generating Facility (WGF). It is the responsibility of the PGs and their engineers to understand and comply with requirements in this TIR including this Appendix A when they are connecting their WGF. Only WGFs are subject to the requirements set forth in this Appendix A. Any requirements not specified in this Appendix A, shall conform to the general requirements set forth else where in the TIR. Any **apparent** inconsistency between the sections must be reported to BC Hydro by the PG or their representative for immediate resolution.

Wind Turbine Generator (WTG) technologies and their behaviour are significantly different from conventional hydro generators or fossil fuel generators. This Appendix A specifically describes the minimum additional requirements for interconnection of a WGF to the BC Hydro System.

The minimum technical requirements specified here do not recommend any preference in the type WTG technology or equipment to be used.

A2. Voltage Ride-through Requirements

In addition to Voltage and Frequency Operation during Disturbance in section 5.4.5**,** and to ensure the security of BC Hydro Transmission System, WGFs are required to stay online during and after system faults if the voltage at high side of WGF step-up transformer(s) connected to the system, which is the point of measurement as shown in Figure A - 1, is within the defined boundaries and shall meet the following requirements:

1. Generators shall remain in-service if the voltage, measured at high voltage terminals of the WGF step-up transformer(s), is within the boundaries shown in Figure A - 2:

    a. During system faults (either multi-phase faults with normal clearing or single line to ground faults with delayed clearing); and

    b. Immediately after the fault is cleared unless clearing the fault effectively disconnects the generator from the interconnected system.

    This requirement does not apply to faults that occur between the generator terminals and the high side of the WGF step-up transformer(s).

2. In the post transient period, generators shall remain in-service during low voltage excursions as specified in WECC Table W-1[5].

3. Following a disturbance, WGF shall return to the pre-disturbance power output, assuming voltage and frequency are within the normal operating range. The reactive power output shall also respond in a controlled fashion to support the system voltage recovery.

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[5] NERC/WECC Planning Standards", Western Electricity Coordinating Council, revised April 10, 2003: Available at: http://www.wecc.biz/documents/library/procedures/planning/WECC-NERC_Planning%20Standards_4-10-03.pdf.

Figure A - 1: Typical Wind Generating Facility Configuration associated with Points of Measurement for Voltage Ride-through and Reactive Power Requirement.

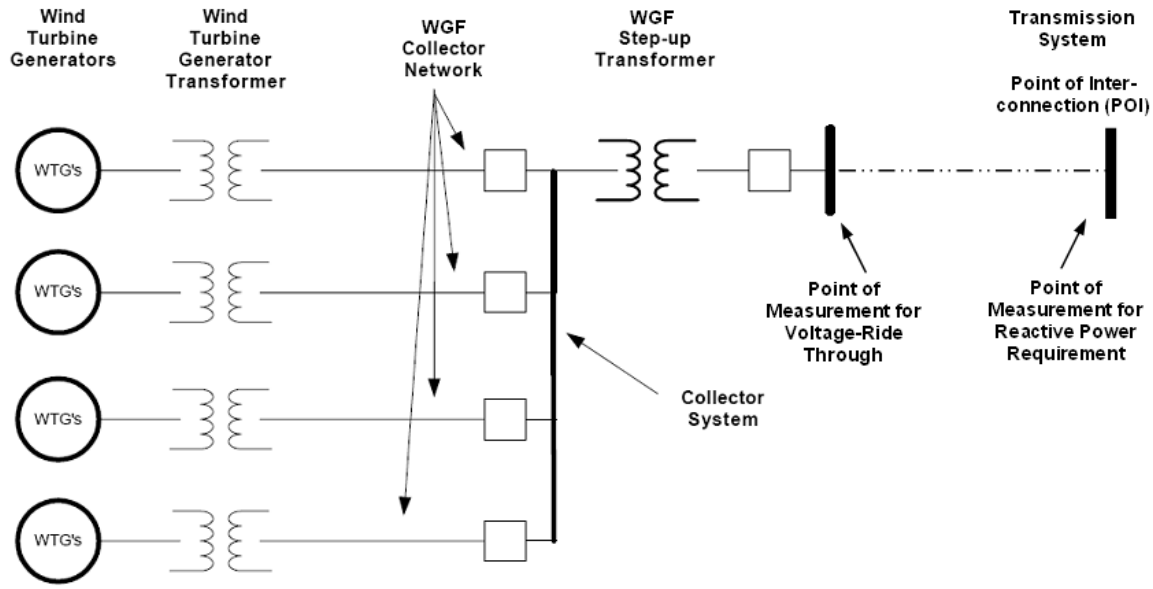
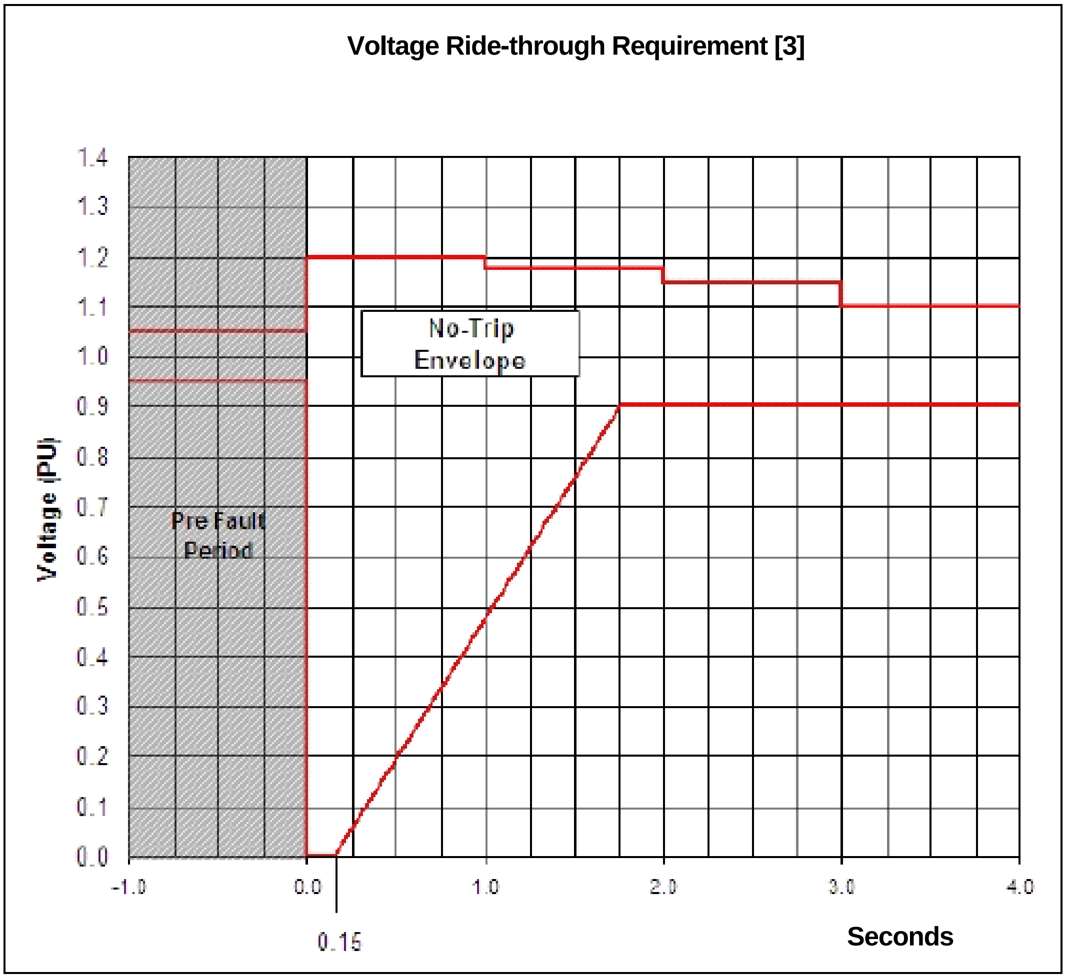


Figure A - 2: Voltage Ride-through Requirement[6]



[6] "The Technical Basis for the New WECC Voltage Ride-through (VRT) Standard", A White Paper Developed by the Wind Generation Task Force (WGTF), June 13, 2007: Available at: http://www.wecc.biz/Standards/Development/WECC-60/Shared%20Documents/The%20Technical%20Basis%20for%20the%20New%20WECC%20Voltage%20Ride-Through%20(VRT).doc

A3. Reactive Power and Voltage regulation

A3.1 Reactive Power Requirements

WGF is required to have a capability providing a range of 0.95 leading to 0.95 lagging power factor as measured at the Point of Interconnection when generating at rated name plate capacity. An adequate amount of reactive power capability shall be available over the full range of operating conditions for various generation levels to ensure acceptable transient, dynamic and steady state voltage performance requirement. This level of capability should be determined based on the operational needs of the WGF.

WGF shall use the appropriate ratio of discrete (mechanically switched shunt capacitors) and dynamic reactive devices (such as rotating machine VAR capability, or equivalent dynamic reactive devices like SVC or STATCOM.), to meet steady-state and transient stability performance requirements based on NERC/WECC planning standards during and after a disturbance. The Interconnection Impact Study will assess the ratio provided by the WGF on a site by site basis based on the system considerations. The dynamic VAR requirement will be finalized based on the final WGF plant design and operation requirements.

A3.1.1 Voltage Operating Limits

Generators within a WGF shall meet the requirements of section 5.4.5.

Note: The Voltage Ride-through (VRT) requirements in section A2 of this Appendix shall override the requirements indicated in Table 7, section 5.4.5.

A3.1.2 Power System Stabilizers and Automatic Voltage Regulation

WTG may not be required to have power system stabilizers.

Automatic voltage regulation is required to automatically regulate the voltage at the POI. The intent of WGF voltage regulation is to be reasonably comparable to synchronous generators to ensure coordinated control behaviour between all types of generating facilities.

Joint VAR control may be required for the WGFs that are closely connected electrically.

For connecting to a strong part of the system, BC Hydro may allow a WGF with installed capacity of less than 10 MVA not to have an automatic voltage regulation system.

A4. Frequency control

A4.1 Frequency Operating Limits

WTG is required to meet the requirements of section 5.4.5.

A4.1.1 Frequency Regulation

WTG capable of an output power level greater than 10 MW may be required to have frequency regulation capability for use under certain islanded operating conditions. If it is required, this requirement will be specified in the Interconnection Impact Study for the proposed project.

A5. Protective Relaying

A5.1 General

WGF shall meet the protective requirements in section 6.

This section amends and clarifies these requirements as they pertain specifically to WGF.

A5.2 Telecommunication Requirements for Protective Relaying Purposes

In addition to the requirements described in section 6 , the following should be noted.

A5.2.1 Direct Transfer trip (Protection)

A single direct transfer trip is required to trip the WGF HV line terminal circuit breaker whenever the remote utility terminal(s) opens or if there has been a protection operation at that line terminal.

This ensures removal of the WGF from the network whenever there has been a transmission line fault.. To keep costs to a minimum, a class 3, as defined by WECC, is acceptable.

A5.2.2 Communications Assisted Protection Tripping

If communications assisted line protection is required (refer to section A5.3 “Line Protection”), the technical requirements will be defined by BC Hydro.

Generally such facilities will be class 1 or class 2 as defined by WECC.

A5.3 Line Protection

Redundant (primary and standby) line relaying facilities shall be provided. For ease of testing and maintenance, duplicate systems are preferred.

A5.3.1 Communications Assisted Protection Tripping

For 230 kV and above system connections, high speed detection of faults for 100% of the transmission circuit shall be provided. Communications assisted relaying (for example, a permissive over/under reaching transfer trip scheme, POTT) for both the primary and standby system must be used. Relaying at the WGF terminal must be of the same type and operating principle as used at the utility line terminals.

For transmission line voltages lower than 230 kV, a communications independent relaying scheme may be acceptable. Acceptability will be determined at the time when the WGF proposal is reviewed.

A5.3.2 Communications independent Relaying Scheme

The transfer trip facilities, described in section A5.2.1 will provide the primary system.

The standby system shall consist of the following facilities at the WGF:

For detection of ground faults:

- Inverse time over-current ground protection with an instantaneous tripping element

For detection of multi-phase faults:

- Timed under-voltage protection connecting to HV Instrument Transformers on the transmission system side of the WGF main transformer.
- Applying carefully selected settings for this protection, paying particular attention to ensure that:
  a. The protection will not mis-operate, based on the WGF ride-through capability;
  b. The protection coordinates with utility protection remote from the connected transmission line; and
  c. The protection coordinates with the remote end line auto reclosing time.

A5.4 Quality Protection

Timed under-voltage, over-voltage, under-frequency and over-frequency protection shall be provided and shall:

- Be set and coordinated with the ride-through capability of the WGF;
- Meet WECC requirements; and
- Meet specific BC Hydro requirements which will be described at the time when the WGF proposal is reviewed by BC Hydro.

A5.5 Under-frequency Protection

Under-frequency load shedding may be required for those instances when the WGF is a load.

Note: Under-frequency load shedding typically has very short time delays (cycles) whereas the under-frequency component of quality protection typically has a much larger time delay (seconds). Under-frequency load shedding settings will be specified by BC Hydro in accordance with WECC requirements. (Refer to section 5.4.5)

A5.6 Disturbance Monitoring

A disturbance monitoring system shall be provided by the WGF and shall be able to:

- Produce records in electronic form as per the latest COMTRADE standard. [Reference: C37.111-1999 IEEE Standard for Common Format for Transient Data Exchange (COMTRADE) for Power Systems.];
- Monitor HV phase and residual line voltage ($3V_o$), HV phase and residual line current ($3I_o$), line protection and entrance protection operations;
- Time synchronization via a GPS clock to 1 ms accuracy; and
- Triggering by line protection or entrance protection operation.

Note: the disturbance monitoring functions can be provided within the protective relay(s) provided as part of line protection and/or entrance protection.

Disturbance records shall be made available to BC Hydro within one week of the disturbance.

A5.7 Information Required from Wind Generating Facility Proponent

In addition to the information requirements described else where in the TIR, the WGF proponent shall provide:

1. Fault current decrement for a close-in as well as remote line end 3 phase faults;
2. Fault current decrement for a remote line end resistive ground fault (value of resistance determined at the time of review); and
3. Confirmation, by actual simulated tests of the WGF line protection, that the WGF HV circuit breaker will be tripped for the faults described in (1) and (2).

Note: if confirmation, satisfactory to BC Hydro, can be provided then the transfer trip facilities described in section A5.2.1 may be waived.

A6. Electric power quality

Power quality requirements for all generating facilities including WGF are described in section 6.4.

The WGF proponent must be aware that energization of the interconnection transformer from the grid will result in a temporary voltage dip. The maximum allowable instantaneous voltage dip on a worst single phase RMS basis is 6% once per eight hours. In some cases, with prior approval from BC Hydro, a voltage dip not exceeding 9% might be allowed.

The WGF proponent is responsible for performing studies where necessary to ensure that they avoid self-excitation and other low-order harmonic resonance phenomenon on their collector system due to shunt capacitors (or cable charging).

A7. System Requirements for Point-of-Interconnection Equipment

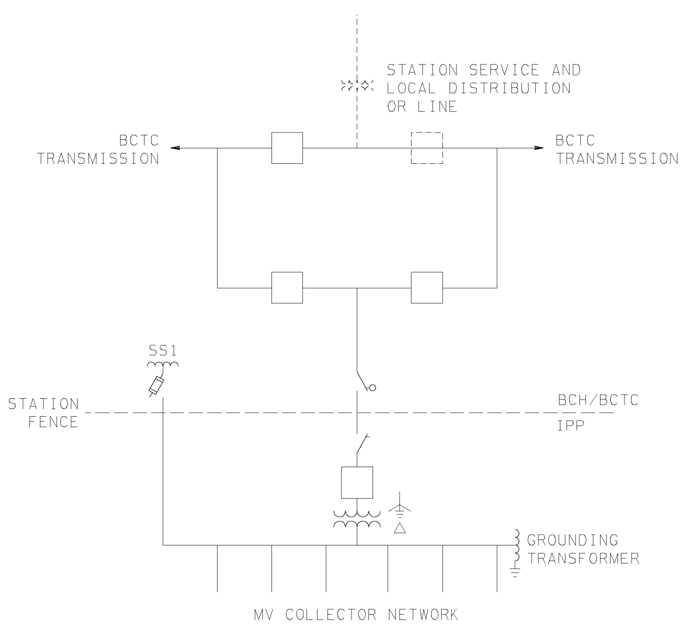
A7.1 Integration Switching Station

WGF interconnection equipment requirements are similar to other generation interconnection with the difference that they are often large relative to most PGFs and have a medium voltage (MV) collector network. Larger generation such a typical WGF must have appropriate grid switching facilities in accordance with Good Utility Practice.

The underlying principle of connecting private networks to the grid is that the grid owner retains control of all switching for events that impact the grid. This means that faults on the independent network shall be cleared first by the independent PG protection with backup clearing by equipment owned and operated by the grid operator to clear the fault without causing an outage to grid lines. Similarly, faults on the grid supplied from an independent PG shall first be cleared by protection and circuit breakers owned and operated by the grid operator with time delayed backup by the independent PG protection. These needs require that independent PG shall always terminate either at an existing grid substation where appropriate switching will be supplied or at a dedicated grid station owned and controlled by the grid operator.

The following diagram illustrates the basic connection arrangement for connecting a WGF to the grid at a nearby transmission line.

Figure A - 3: Basic Connection Arrangement for Connecting a WGF



Comments on the Point of Interconnection requirement are as follows:

The WGF proponent will not have physical access to the grid station for operational purposes once the station is energized and so will require the necessary switching and isolation equipment on its side of the ownership boundary which will be delineated by a fence.

Station service power is required in the grid station. It may be necessary at remote sites to provide a dedicated step-down transformer from the HV bus as the primary supply but normally the service power supply can be obtained from the WGF station or from local distribution.

A7.2 System Grounding

The transmission system must be effectively grounded to keep transient voltages within the over-voltage withstand capability of system equipment.

This requires that all generation sources feeding into the grid via transformers are effectively grounded on the HV side.

A7.3 Grid Connection Transformer

The general equipment requirements for insulation and fault withstand are as for any other grid connection and are covered else where in the TIR.

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 so as 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.

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.

A8. Transmission System Operation

The WGF proponent is responsible for the validity of information (data, models and associated settings) that it or its supplier submits to BC Hydro so the latter can conduct the real-time operational studies required to assess the impact of operating the WGF to the transmission system.

A8.1 Data Requirements

BC Hydro requires real-time data from each generating plant for effective operation of the BC Hydro System. This data must be provided in a form compatible with transmission provider equipment. The real-time data required for all types of generating plants depends on their capacity and is specified in the Table 8, Table 9, and Table 10 in section 8.5. The following are additional requirements for WGF:

- 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[7] in addition to what is listed in Table 8, Table 9, and Table 10 in section 8.5:
  - MW (same time resolution as in Table 8, Table 9, and Table 10);
  - MVAR (same time resolution as in Table 8, Table 9, and Table 10);
  - MW.h (hourly);
  - Average wind speed (every 10 seconds, if required, for the wind turbine generators connected to the feeder); and
  - Average wind direction (every 10 seconds, if required, for the wind turbine generators 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 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.
- The additional data noted above shall be transmitted to the System Operator in the same SCADA data channel as the data noted in Table 8, Table 9, and Table 10. This will usually result in a higher bandwidth SCADA channel than for non-wind PGs.

A8.2 Dispatchability and Curtailability

BC Hydro will curtail a generator for reliability reasons in the BC Hydro System. The WGF shall be able to complete the curtailment amount within 10 minutes of notification to the generator owner/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.

[7] 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.

A8.3 Special Communications Requirements for Wind Generating Facilities

BC Hydro shall be notified by the WGF owner/operator within 10 minutes of an event resulting in a reduction in the WGF capacity of greater than 75 MVA for any reasons including high wind.

A8.4 Planned Outage Coordination

See BC Hydro System Operating Order 1T-22 for detailed procedures. This System Operating Order is available at http://transmission.bchydro.com/transmission_system/reliability/.

A8.5 Ramp Up/Down Limitation

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.

A9. Responsibility for Technical Information to be Submitted to BC Hydro

The WGF proponent is responsible for the validity of information (data, models and associated settings) that it or its supplier submits to BC Hydro so the latter can conduct the studies required to assess the impact of connecting the WGF to the Transmission System.

WGF system models including load-flow, transient and dynamic models, as required by BC Hydro, shall be submitted to BC Hydro in a timely manner for Interconnection Studies..

A9.1 Information Required for Dynamic Modelling

The WGF proponent is responsible for providing in a timely manner a detailed simulation model of the WGF in Siemens PTI's PSS/E format to BC Hydro for Interconnection Impact Studies.

After commissioning tests of the WGF are completed, the final models and parameters in Siemens PTI's PSSE format and also in GE PSLF format shall be provided to BC Hydro.

The WGF proponent shall provide compliance tests demonstrating that the provided model behaves like the installed WTG. 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.

The WGF proponent must provide BC Hydro permission to share all WGF modeling data with reliability organizations such as WECC, NWPP, and NERC, and with members of those entities who have permission to access that information.

A10. EMTP Modeling Information

A proven EMTP (electromagnetic transients program), specifically PSCAD/EMTDC, model of each proposed WTG 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 of the WGF 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 model will force BC Hydro to take a more conservative approach to the design and may result in a significant additional cost to the WGF proponent. More detailed requirements of the model are provided in Appendix 1 below.

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".

A11. Other Considerations

BC Hydro may require that:

- Some or all of the generators in the WGF may be required to be tripped after a contingency by a special protection system such as a generation shedding RAS;
- Any WGF greater than 10 MW be equipped with a control system to receive control signals for such functions as limiting maximum real power; and
- A control system be added to gradually shut down the wind generators.

A11.1 Black Start Capability

BC Hydro does not require that the WGF have black start capability. However, it is up to the WGF proponent to decide, in consultation with their engineer, whether black start is a necessity for the WGF to self-start and energize the WGF while the WGF is isolated from BC Hydro System at the Point of Interconnection.

A11.2 Back-up Power

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

A11.3 Black Start Disconnection

A means shall be provided by the WGF proponent 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 Point of Interconnection. 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.

A12. Commissioning

See BC Hydro System Operating Order 1T-35, section 2 for details. This System Operating Order is available at http://transmission.bchydro.com/transmission_system/reliability/ .

A12.1 Special Factory and Commissioning Tests for Wind Turbine Generators

The following tests are required for the applicable type of Wind Turbine Generators:

- 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 Wind Turbine Generator behaviour does not conform to the model, the WGF proponent is responsible for any additional costs for interconnection to the Transmission System.

APPENDIX 1

INFORMATION REQUIRED FOR MODELLING IN PSCAD/EMTDC PROGRAM

A PSCAD model of the proposed Wind Turbine Generator must be provided to BC Hydro for Interconnection Impact Studies. The requirements of the model are:

Essential Requirements:

- Detailed modelling of the main components, the controls, automatic voltage regulations, and protections must be included.
- Blade/pitch controller is to be included.
- The ride-through capability is to be modelled.
- The model is to be capable of correctly reproducing the short circuit fault current contribution.
- The model must be suitable for modeling open circuit, short circuit, balanced and unbalanced faults in the grid, including steady state & dynamic simulations.
- The model should be available in the latest version of PSCAD and should support Compaq Fortran 90 V6.6.
- 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 PSCAD model, where, for example, one model might represent a cluster of wind turbine generators connected to one branch of a WGF.
- The model should support the “snapshot” feature in PSCAD to allow the simulation to be saved and restarted at any point in time.
- The model must come with documentation to explain the assumptions and basic operation of what is being modelled as well as a user manual.
- Model validation documents comparing the PSCAD model response to real system measurements must be provided.
- The control of internal and external shunt capacitor banks, as required by the overall controller, is to be included.
- A correctly functioning PSCAD case including the WGF model connected to a simple AC system must be provided.

Non-essential Requirements:

- Switching-based model (for doubly fed, SVC and converter based models) for harmonic/power quality studies must be provided.
- Blade dynamics (i.e. inertia of blades, gearbox, etc.) should be modelled for torsional interaction/dynamic studies.

"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
- 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 a PSCAD model of the wind turbine generator be provided, the following additional information should be provided:

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

Appendix B – Protection Example Installations

Figure B - 1: PG Line Protection Utilizing Multi-function Distance Relays*

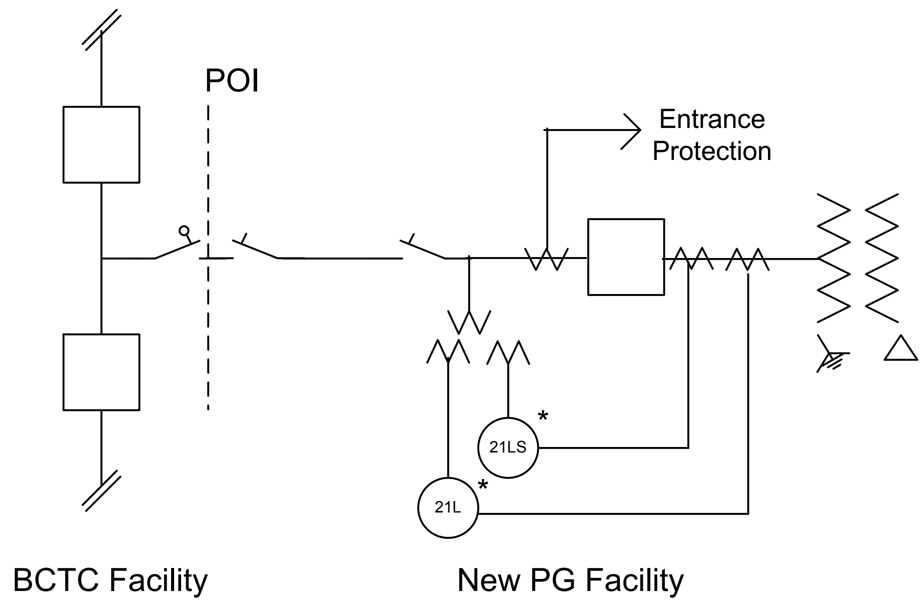
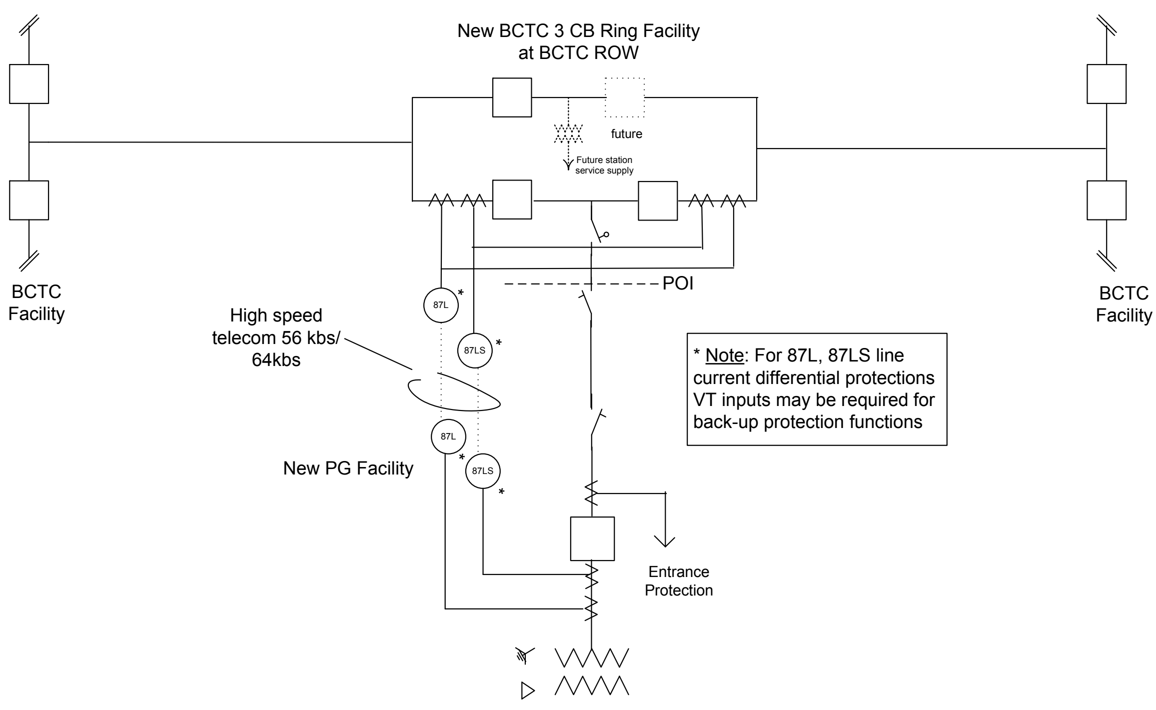


Figure B - 2: PG Line Protection Utilizing Line Current Differential Protection



Appendix C – Power Parameter Information System

C1. General Description

The Power Parameter Information System (PPIS) monitors and records individual power-line electrical parameters (KW, kVAR, kV, kVA, PF, Hz, Harmonics, Transients, Min, Max, Events and etc.) The PPIS is usually installed at the PGF but another suitable location may be selected with agreement between the PG and BC Hydro. Supplied and installed by PG including hardware and software program. The on-line 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 PG and BC Hydro technical personnel.

C2. Power Parameter Information System Requirements

The PPIS consists of a multi-profile power meter with local display unit; protection grade voltage transformers (VT, 120V secondary) and current transformers (CT, 5A secondary); FT-1 type test blocks or alternatively, revenue type blocks; analogue business telephone line with facility entrance protection; telephone modem (set at 9600 Baud); RS232 modem cable; and an un-interruptible power supply (UPS). These components are interconnected to provide power parameter information via either the local display unit or remote access with application software acceptable to BC Hydro.

The full three-phase VTs and CTs (including optional transformer neutral CT where required) installed at the PGF are the input source to the power meter. The VT and CT test blocks are for testing and maintenance purposes, while the telephone modem provides remote access, and the UPS ensures minimum of 4 hours of PPIS operation during power outage. The PPIS system is preferably installed indoors in the control cubicle with front mounted local display unit, but may be located in an individual cabinet beside the revenue metering cabinet if necessary.

C3. Commissioning

The PPIS system shall be commissioned by the PG prior to generator operation. It shall be checked, tested and recorded for correct wiring, phasing, voltage and current levels as well as functional tests for local and remote access by BC Hydro. The PPIS configuration, programming, settings and recordings tasks are to be done by BC Hydro technical personnel.

C4. Operation and Maintenance

BC Hydro will connect to PPIS on-line and/or periodic download the captured information. This system requires very low maintenance. However, BC Hydro requires access to the system on site for inspection, testing and calibration purposes.

Figure C - 1: PPIS Reference Drawing 1

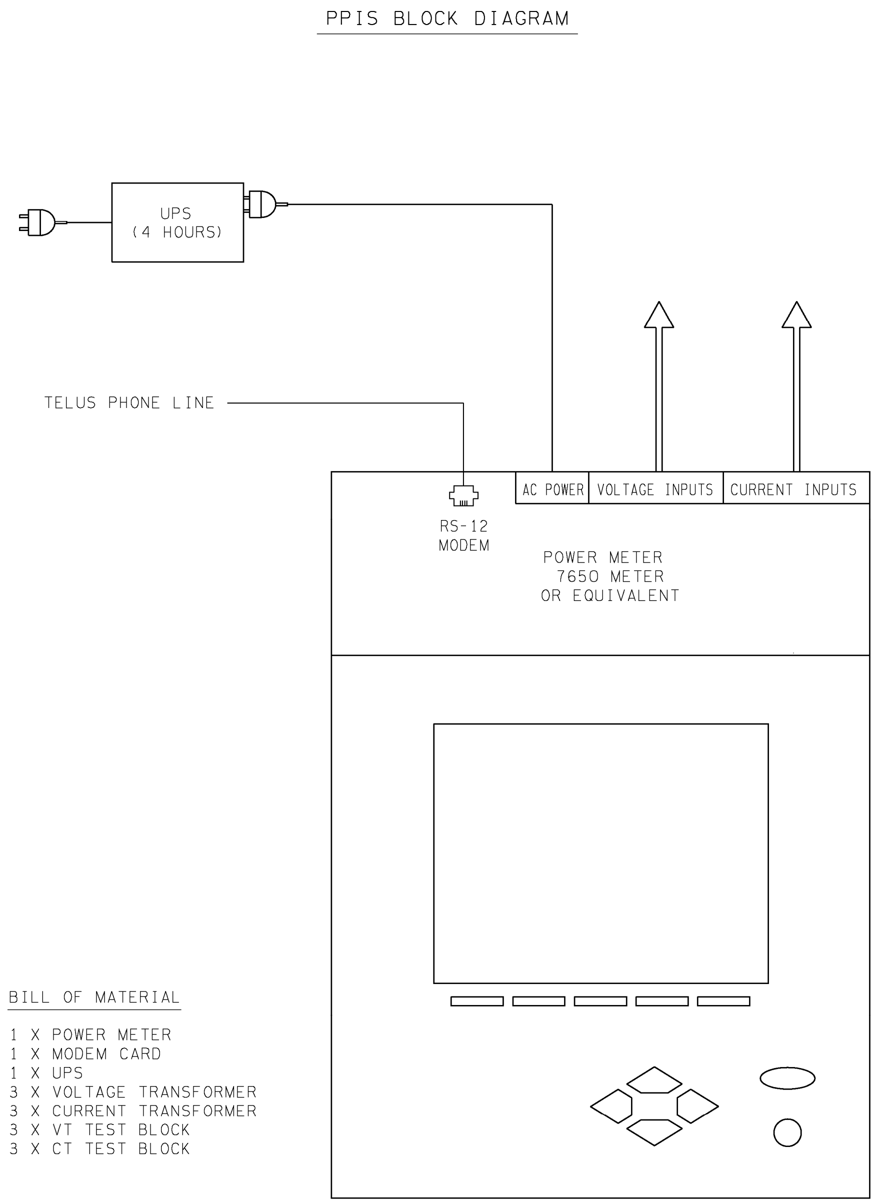
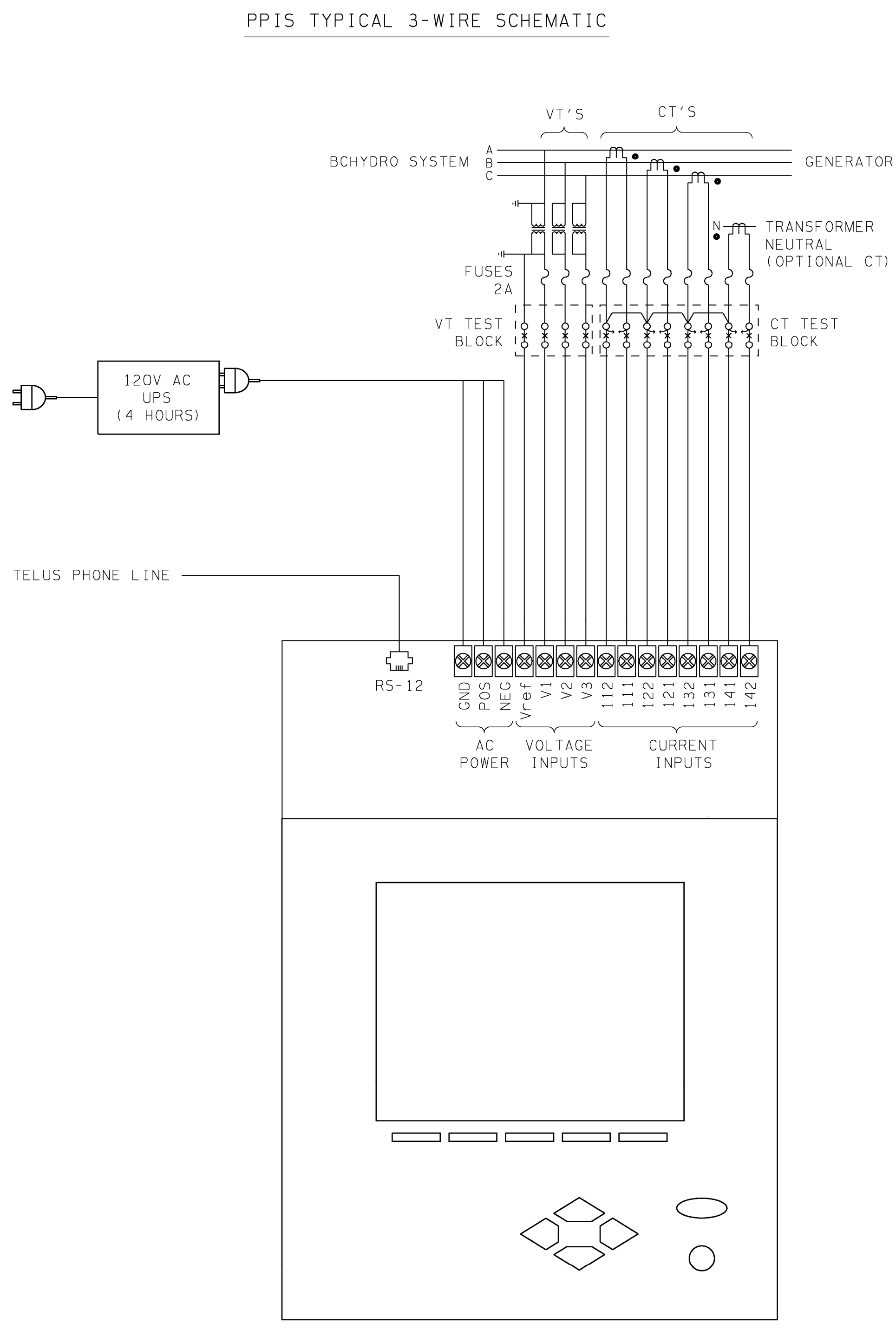


Figure C - 2: PPIS Reference Drawing 2



Appendix D – 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.

D1 Submission Requirements

D1.1 Format

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

The preferred format for reports and other documents is Word for Microsoft Office; for data, drawing indexes and the like is Excel for Microsoft Office.

The preferred formats for drawings are (in order of preference): (i) Auto-CADD *.DXF format, (ii) Intergraph MicroStation*.DGN format, and (iii) 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 Equipment Statement (GIES), which is located on the BC Hydro website. The PG shall provide one paper 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 GIES shall be provided as both paper and electronic copy.

D1.2 Typical Information and Data for PG Interconnection Studies

D1.2.1 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.

D.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, hydro, co-generation, geothermal, etc.)
- Number of rotating generators
- 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, PG 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, lb. Ft2

  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

2.3 Generator Data, 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 (lb-ft2), 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:

- Nominal operating voltage, kV
- Line length, KM
- Line capacity, amps at ºC
- Overhead/underground construction
- Positive and zero sequence transmission line characteristics in primary values

  a) Series resistance, R Ω
  b) Series reactance, X Ω
  c) Shunt susceptance, B μ S (or μ Ω –1)

D1.3 EMTP Data

The following data is required:

- 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

D2. Generating Unit Testing and Model Validation

D2.1 Generating Facility Data

- The PG shall provide to BC Hydro the information for the PGF as specified in the WECC "***Generating Facility Data Requirements***[8]***"***.
- The PG shall review, verify and update the PGF data when any of the following conditions occur:
  - No later than 180 days after the new PGF is released for Commercial Operation.
  - No later than 180 days after an existing generating unit re-starts Commercial Operation with modified equipment, control settings, or software that influences the behaviour of the plant with respect to the grid (e.g. excitation retrofit, additional control function within a controller, turbine modification, voltage regulator and power system stabilizer tuning modification, etc.)
  - At least once every five years.

[8] *The Generating Facility Data Requirements document*" and *Generating Unit Baseline Test Requirements document* can be found at www.wecc.biz.

D2.2 Baseline Testing

- The GP shall test the generating unit and validate its model data.
- The GP shall provide test and validation reports to BC Hydro. For guidance on the test requirements, refer to the current WECC "***Generating Unit Baseline Test Requirements***[1]".
- The testing and associated validation by simulation shall be performed on a generating unit when any of the following conditions have occurred:
    - If the generating project has not been certified by WECC under Generator Testing Program since January 1997.
    - No later than 180 days after the new PGF is released for Commercial Operation. In the meantime, the PG shall provide the best available model data supplied by the equipment manufacturer using the WECC approved models including commissioning reports.
    - No later than 180 days after an existing generating unit re-starts Commercial Operation with modified equipment, control settings, or software that influences its behaviour with respect to the grid (e.g. excitation retrofit, additional control function within a controller, turbine modification, voltage regulator and power system stabilizer tuning modification, etc.), only those portions of the generating unit model that can be influenced by the modifications need to be tested and validated.
    - No later than 180 days after the PG is notified by WECC that there is evidence that the modeled response of a PGF does not correlate with the actual response, except in instances where the lack of correlation was caused by equipment problems that were subsequently corrected.

D2.3 Model Data Validation

- The PG shall perform model data validation and provide a report to BC Hydro at least once every five years. Schedule of model validation shall be coordinated between the PG and BC Hydro.
    - The WECC "***Generating Facility Model Data Validation Requirements***[9]" document describes acceptable methods of model data validation by performance comparison.
    - The PG shall verify that generator control limiters, protection and equipment capabilities are consistent with those reported in the model(s).

[9] The WECC *Generating Facility Model Data Validation Requirements* can be found at www.wecc.biz

D2.4 Generator Outage Data

The PG is expected to submit generator outage data within 15 days of the end of each month to the Canadian Electricity Association (CEA) and to the North American Electric Reliability Council (NERC) in the United States.

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 PG with a copy of such order.

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

Appendix E – Declaration of Compatibility

The PG shall comply with the various levels of Declarations of Compatibility as listed below and available at the BC Hydro website. Please see System Operating Order 1T-35 at transmission.bchydro.com/NR/rdonlyres/610E3D35-3383-4A3A-8DAB-0AFF27846AF6/0/1T35.pdf. These declarations refer to key aspects where BC Hydro must be confident of the correct operation, setting, calibration and/or installation of equipment.

Each declaration must be signed by BC Hydro and the PG agreeing that the PG's interconnection is compatible with the Transmission System and is capable of receiving electricity, generating electricity for commissioning purposes, or full commercial generating electricity.

This may include, but is not limited to, generator performance, protective relaying, telecommunications, revenue metering, and shall confirm the compatibility of the PG's equipment and controls.

Requirements for "Declaration of Compatibility - Load"

The compatibility of load describes conditions that must be satisfied before the PGF can be connected to receive electricity from the Transmission System and usually occurs during construction.

Requirements for "Declaration of Compatibility – Generator (1st Synchronization)"

The compatibility of generation (1st Synchronization) describes conditions that must be satisfied before the PGF can be connected to generate electricity for the purposes of testing and commissioning the facility or its components.

Requirements for "Declaration of Compatibility – Generator (Operating)"

The compatibility of generation (operating) describes conditions that must be satisfied before the PGF can be connected to commercially generate electricity.

Appendix F – Permissible Voltage Dips – Borderline of Visibility Curve