BC hydro

CONNECTION REQUIREMENTS FOR UTILITY or NON-UTILITY GENERATION, 35 KV AND BELOW

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1.0 INTRODUCTION

1.1 Purpose

This document was prepared by BC Hydro (BCH) to guide generator owners and proponents in connecting generators to the BCH distribution system at 35 kV and below. This guide applies to all generators, whether utility or non-utility owned, and these generating plants are referred to in this guide as a **Producer**. Generators can be subdivided into attributes such as energy source, type of prime mover, cogeneration capability (electricity generation plus heat or steam), rotating machines and dc-ac conversion.

The three main types of generators connecting to the BCH integrated distribution system are:

- plants whose output will be sold to BCH Power Supply and/or Powerex under a purchase agreement,
- self-generation load displacement plants. These are BCH electricity customers with self-owned generation operating in parallel with the BCH supply but no export to BCH across the BCH revenue meter. BCH installs a detented revenue meter that cannot reverse register, i.e. no “net metering”,
- generator test facilities. These are specialized sites where the owner is testing generators or generator packages and uses BCH as a load bank for a BCH payment of zero for electricity exported to BCH across the BCH revenue meter. These sites are coincidentally load displacement plants.

While this guide is intended primarily for generators connecting to the BCH integrated distribution system, it can also be applied in BCH non-integrated areas but added requirements may apply for:

- BCH revenue and power quality metering,
- synchronous generator voltage and frequency performance on making/shedding load,
- application of annual availability factors to the Producer’s equipment

This guide is written for generation based on rotating machines (synchronous and induction generators). This guide is not written for dc-ac conversion such as fuel cells and photovoltaic arrays. However, parts of this guide do apply to dc-ac conversion plants, which BCH addresses case-by-case. Dc-ac conversion plants are different from rotating machines in that fault currents are typically only marginally greater than full load current but harmonic current injection to BCH is carefully assessed.

This guide describes BCH connection requirements, the minimum design standards the generation developments must satisfy, and the range of normal and emergency system conditions the generation facilities could encounter while connected to the BCH distribution system.

When information on the location, size and type of the generation development is received, BCH will provide site-specific information such as connection voltage, short circuit level, technical requirements, plus BCH line extension and equipment upgrade costs payable by the Producer.

The information contained in this guide is subject to change and may be revised at any time.

For generators connected at transmission voltage (69 kV & up), refer to the publication "BC Hydro Connection Requirements for Independent Power Producers Supplying at 69 kV to 287 kV, November 1994".

1.2 Intent

The intent of this guide is:

(a) to assist BCH in the attainment of the common goal that the design, construction and operation of the generation plant, will:

- be compatible with and safe at all times for the BCH equipment and system, for BCH employees or agents, for BCH customers and the general public,
- maintain a high standard of quality and reliability of electricity supply to BCH customers,
- meet operating, dispatching, metering and protection requirements.

(b) to facilitate timely and efficient handling by BCH of information provided by the proponent relevant to design, construction and operation of the generating plant.

1.3 Limitations

Important notes of limitations include:

(a) this guide is not intended or provided by BCH as a design specification or as an instruction manual for the Producer, his employees or agents and the guide shall not be used by the proponent, his employees or agents for those purposes. Persons using information included in the guide do so at no risk to BCH and they rely solely upon themselves to insure that their use of all or part of this guide is appropriate in the particular circumstance,

(b) the generator proponent, his employees or agents recognize that they are, at all times, solely responsible for the generator plant design, construction or operation. BCH, its employees or agents shall not be or become the agent of the proponent in any manner howsoever arising,

(c) the advice by BCH, its employees or agents, that the generating plant design or equipment meets certain BCH requirements does not mean, expressly or by implication, that all or any of the requirements of the law or good Engineering practices have been met by the owner and such judgement shall not be construed by the owner or others as an endorsement of the design or as a warranty by BCH, its employees and agents, of the design or equipment, or any part thereof.

1.4 Project Requirements

BCH has operating, metering and protection requirements for generators connected with its distribution system. These requirements vary according to the type, size and location of the generation project. Additional requirements not found in this guide may be necessary as a result of findings of technical studies that BCH will undertake when the size and location of the generation development has been identified. These requirements are designed to protect BCH facilities and customers, and are not designed to protect the Producer’s facilities.

In general, the Producer will own and is responsible for the design, installation, operation, and maintenance of all necessary generation, station, and line facilities that are required to connect its facilities to the BCH distribution system, unless otherwise agreed in writing. The developer is responsible for obtaining all regulatory approvals, including Environmental Assessment approvals if necessary. The facilities shall be designed, constructed, and operated in compliance with the applicable statues, regulations, by-laws, and codes.

The Producer is responsible for submitting all specifications of its facilities and detailed plans to BCH for review and approval prior to receiving permission to connect to the BCH system. BCH review and approval 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 generation facilities. BCH shall not, by reason of such review or lack of review, be responsible for the strength, adequacy of design, or capacity of equipment built pursuant to such specifications, nor shall BCH be responsible for any injury to the public and workers resulting from the failure of the generation facilities.

2.0 SUBMISSION REQUIREMENTS

2.1 General Requirements

The differentiation of BCH requirements by individual generator rating is summarized as follows:

(a) all generators in parallel with BCH:
- power quality protection, i.e. under/over voltage and under/over frequency relaying to protect BCH customers from voltage and frequency excursions,
- a maintenance plan forwarded annually to BCH.

(b) generating plants rated 200 kW and up:
- will **generally** require an entrance circuit breaker (CB) or recloser for protection tripping. An example of a possible exception is where a generator is added to an existing facility which already has a main transformer and entrance fuses. Conversely, some plants below 200 kW may require an entrance circuit breaker.

(c) generating plants rated 500 kW and up:
- synchronous generator rated power factor shall be at least 0.90 lag (generating) to 0.95 lead (absorbing); BCH may require a lower power factor rating in some cases,
- will generally be required to provide some reactive power to BCH,
- protective relays shall be utility grade,
- each set of protection and each circuit breaker shall be supplied from physically separated and separately protected dc circuits.

(d) generating plants rated 1000 kW and up:
- additional generator and prime mover data is required,
- the excitation system shall have a fast response,
- a neutral reactor is normally required between the transformer HV star point and ground to aid BCH ground fault overcurrent detection for a SLG fault near the Producer,
- shall have failure protection for entrance circuit breaker.

2.2 Information Required for Formal Review

The Producer's submission shall include the following:

(a) a copy of completed "Statement to B.C. Hydro Regarding Primary Voltage Service Entrance Equipment", BCH form 70340, (Appendix 1), for plants connecting to BC Hydro at primary voltage . This form shall be signed by either a registered Professional Engineer or be approved by the electrical inspection authority having jurisdiction over this plant,

(b) three copies of a map at a scale no greater than 50,000:1, preferably on B-size (43 cm X 28 cm paper), showing the proposed location of the generating station and existing BCH distribution and/or transmission line,

(c) three copies of generating station site plan showing the location of the generating plant and the proposed terminal pole or service manhole with the routing of aerial line or underground cables on private property to the generating station,

(d) three copies of generating station electrical one-line diagram showing:
- the connections of all substation equipment with voltage levels and equipment ratings,
- all circuit breakers with applicable relay functions, plus fuses with fuse type and rating, from the point of connection to the generator(s),
- the location of the revenue metering equipment.

(e) one copy of protective device coordination graph showing coordination between the generating plant and BCH protective devices, including circuit breaker control wiring diagram and key interlock scheme if applicable. A standard size 4-½ x 5 cycle log-log graph shall be used for the coordination study. The plant's service entrance protective device settings must be compatible and coordinate with BCH protective equipment. A simplified coordination graph is shown in Appendix 2, Drawing PG-DTS-A4. The consultant will normally enhance this sample and produce a TC protection coordination graph for 3-phase faults and a separate TC graph for ground faults, each TC graph showing:
- generator transformer inrush current and damage curve,
- 4 vertical lines representing maximum and minimum short-circuit current contribution from the 2 sources for faults at the BCH protection device and the HV side of the generator transformer, i.e. min generator contribution (fault at BCH protection device), max generator contribution (fault at Producer terminal), min & max BCH contributions (fault at Producer's terminal),
- generator CB and entrance CB or fuse overcurrent curves,
- BCH CB or fuse overcurrent curve including instantaneous setting where enabled.

(f) three copies of drawings showing provision for the BCH metering transformer, metering cubicle and required cabling and wiring. Some or all of this information can be shown on the station electrical one-line diagram,

(g) the following additional information for generators rated 1 MW and up, some of which appears on BCH Form 70340:

General
(i) energy source (hydraulic, gas, wood waste or others),
(ii) type (synchronous, induction, dc with inverter or others),
(iii) installed capacity; number and size of units,
(iv) annual energy to be sold to BCH and expected annual capacity factor.

Machine (for each unit)
(i) rated MVA, voltage and lag/lead power factor rating,
(ii) inertia Constant (H in MW-sec/MVA) of the combined generator and turbine. Alternatively the moment of inertia (WR^2) and the synchronous speed may be given,
(iii) unsaturated values of time constants and reactances, i.e.:
Open circuit time constants
T'_{do}, T''_{do}, T'_{qo}, T''_{qo}
Reactances in per unit on the generator MVA base:
X_d, X_q, X'_d, X'_q, X''_d and X''_q
(iv) open circuit saturation characteristic.

Exciter
(i) manufacturer and type of exciter or IEEE model type.

Speed Governor
(i) where a governor is planned, block diagram or IEEE standard model type with parameters.

3.0 SYSTEM CONSIDERATIONS

In accordance with the T&D Interconnection Agreement (legal document of rights/responsibilities of both parties), the Producer will be required to discontinue parallel operation when requested by BCH under situations such as:

(a) to facilitate maintenance, test or repair of BCH facilities,
(b) during BCH system emergencies,
(c) when an inspection of the parallel generating equipment reveals a condition hazardous to the BCH system or to employee or public safety,
(d) when the Producer fails to supply electricity in accordance with the T&D Interconnection Agreement.

The Producer will pay, prior to connection, BCH equipment costs associated with BCH distribution line extension to the Producer, feeder upgrades, substation/transmission protection upgrades, substation capacity additions, communication and control and load measurement.

3.1 Range of System Conditions

B.C. Hydro's primary distribution system is a three-phase four-wire multi-grounded common neutral system. The primary distribution voltages are:

(a) 2,400 V/4,160 V GRD Y,
(b) 7,200 V/12,470 V GRD Y,

(c) 14,440 V/24,940 V GRD Y,
(d) 19,920 V/34,500 V GRD Y currently used only in some rural locations in the Northern Region.

Secondary voltage classes available are 120/240 V 1-phase, and 120/208 V and 347/600 V 3-phase 4-wire.

The LV bus at BCH distribution substations is generally regulated by station transformer automatic load tap changing (LTC) with a set point of about 124 V (7.44/12.89 kV or 14.88/25.77 kV), or by 3-phase 300/400 A feeder position voltage regulators or bus regulators with a setpoint of 122-123 V. (120.0 V on a secondary basis is equivalent to BCH nominal primary voltages of 7.2/12.47 kV and 14.4/25.0 kV). Typical regulator bandwidth is +/- 1.5 V, and typical time delay varies from 30-70 seconds.

The Producer shall adequately design and protect the generating plant against the impact of switching operations and contingencies in the BCH system. Some examples are as follows:

(a) load rejection on the generating plant will cause overspeed and overvoltages in the plant. The amount of overspeed and overvoltage will be a function of the electro-mechanical parameters of the interconnected system and that of the generating plant.

(b) self-excitation can occur where an islanded distribution/transmission system, left connected to the generating plant, represents a capacitive load in excess of the synchronous generator capability to absorb it. The generating plant may be damaged by the resulting overvoltage if the plant is not quickly disconnected from the distribution system.

    Where BCH substation or feeder shunt capacitors exist, BCH will assess the risk to its own and Producer equipment due to voltage transients and resonance arising from capacitor bank switching.

(c) BCH substation feeder circuit breakers are automatically reclosed in some cases and no auto reclose in other cases. Supervisory control of feeder breakers from the BCH Area Control Centre is available in some cases. Additionally, automatic reclosers are common out in the feeder in rural areas. Line reclosing by BCH could connect an islanded Producer to the BCH system when the two systems are out of synchronism. To prevent the Producer’s generator, switchgear or BCH customer equipment from being damaged by a BCH out-of-synchronism close, voltage supervision can be added to the BCH line reclosers to block close of automatic line reclosers if voltage is present or added to the Producer side of the BCH substation feeder breaker to prevent supervisory close if voltage is on the feeder.

(d) acceleration of the generating plant during faults on nearby BCH distribution feeders could cause the plant to slip out of synchronism with the BCH system.

3.2 Islanding

Islanding occurs when a portion of BC Hydro's load becomes isolated from the BCH substation, but remains connected to the Producer for an indefinite time, such as when the BCH substation feeder breaker opens via local protection during a substation transformer or bus fault, or following lockout of a feeder line recloser.

To avoid the risk of damaging customer equipment due to abnormal voltage or frequency arising from a mismatch between generator capacity and load, the Producer should promptly automatically disconnect from the feeder when it becomes isolated from the utility system. The intent of power quality protection (over/under voltage and over/under frequency relays) is to initiate this Producer disconnection. Producer islanding of BCH customer load may also result in voltage flicker, increased harmonic generation or miscoordination of protective devices if a fault occurs.

3.2.1 Synchronous Generators

Small Producers typically have limited turbine/generator control. However, the probability of such an isolated system continuing to operate increases as the amount of isolated load approaches the capacity of the parallel generator.

See Section 7.2.2 for guidelines on typical relay settings during parallel operation. When BCH power resumes following Producer separation, an orderly re-establishment of parallel operation shall be arranged between the BCH Area Control Centre and the Producer.

BCH may require the Producer to provide control and communication equipment to allow automatic transfer tripping of the Producer's entrance circuit breaker upon opening of the BCH substation feeder breaker or line recloser.

In very rare cases, BCH may wish the Producer to supply BCH customers on the healthy portion of the feeder during a prolonged feeder, substation or transmission outage, i.e. island BCH customer load. This operation should be possible where the Producer employs synchronous generator(s) with sufficient capacity and adequate controls and protection devices to maintain voltage and frequency within acceptable limits. The Producer's protection must be able to trip and clear all possible faults in the distribution feeder while islanding. A suitable means must be employed to ensure that BCH cannot inadvertently close out-of-synchronism on the Producer's rotating generator.

3.2.2 Induction Generators

An induction generator that has become separated from the utility may be connected to an amount of shunt capacitance that will sustained self-excitation. Also, resonance may occur between the magnetizing inductance of the generator and the connected capacitance to produce damaging overvoltages.

Lightly loaded induction generators can produce an overvoltage of 2 pu or more on separation from the utility. Fast tripping of the generator by overvoltage protection may be required. In other cases, a slow rise in voltage but an instantaneous increase in frequency may occur if the isolated load is less than generator output. The slip will decrease instantaneously as the load suddenly drops, yielding a higher frequency and momentary increase in load as motors speed up. As motors reach their new speed the voltage rises. The voltage and frequency will continue to increase until the load has absorbed the entire generator output. For this case, tripping by fast overfrequency relays may be required.

3.3 Quality of Electricity Generated

The operation of the Producer's generator(s) shall not degrade the quality of electricity in the BCH system. Some examples of degrading the quality of electricity are:

(a) introduction of harmonics into the BCH power system,
(b) creation of abnormal voltage and frequency excursions in the BCH power system,
(c) depression or elevation of the steady-state voltage level outside the normal operating range,
(d) creation of an unacceptable voltage unbalance between phases.

Steady-State Voltage

BCH delivers electricity to consumer service entrances at a voltage according to CSA Standard CAN3-C235-83, "Preferred Voltage Levels for AC Systems, 0 to 50,000 V", which defines steady-state voltage variation limits at consumer service entrances up to 1000 V as follows:

	Variation From Nominal Voltage (on 120 Volt Base)	
	Normal Operating Range	**Extreme Operating Range**
Voltage at 1-Phase 120/240 V Service Entrance	110/220 - 125/250 V	106/212 - 127/254 V

The 2 ranges above do not apply under abnormal or fault conditions or temporary conditions such as magnetizing inrush currents and motor starting. Voltages outside the normal range but within the extreme range are corrected on a planned basis.

BCH Line Voltage Regulators

BCH uses automatic step voltage regulators in voltage-limited distribution feeders. Very long rural lines may have up to four line voltage regulators in series beyond the distribution substation. Introduction of a large Producer (say 1 MW and up) in a long rural feeder often results in both the real kW flow and reactive kvar flow changing directions daily or seasonally out in the feeder. Line voltage regulators subjected to reverse power flow may need to be retrofitted with controls for reverse power. However, the regulator reference voltage is always the BCH distribution substation source bus voltage so the regulator always alters the feeder voltage profile with respect to the BCH source.

3.4 Voltage Flicker

Voltage flicker is an increase or decrease in voltage over a short period of time, normally associated with motor starting or fluctuating load. The characteristics of a particular flicker problem depend on the characteristics of the load change.

A voltage flicker problem may occur when:
(a) an induction generator is started and accelerated as a motor,

(b) an induction generator is connected or disconnected to the utility,
(c) when a large generator transformer is energized from a weak BCH feeder, where transformer inrush current may be 8-12 types full load current, depending on the point on the voltage waveform at which connection occurs and the remnant flux in the generator transformer. BCH may require, in some cases of low fault level in the feeder, that the Producer energize their substation transformer at all times from their generator(s), rather from the live feeder,
(d) when a large Producer sheds or makes a significant block of load.

All Producers shall take steps to minimize flicker problems from their generator(s).

The standards for voltage flicker at the point of connection of the Producer's generator(s) with BCH are as follows:

Voltage Dip	**Number of Times Permitted Not to Exceed**
3.3% of normal voltage	up to once per hour in urban systems supplying many customers
6.5% of normal voltage	up to once per hour in rural systems supplying few customers

Voltage dips exceeding 6.5% but not exceeding 9% may be permitted by BCH at predetermined times which are acceptable to BCH. Voltage dips more frequent than once per hour must be limited to the "Borderline of Irritation" curve of Appendix 3, "B.C. Hydro's Voltage Flicker Limits".

3.5 Harmonic Limitations

The harmonic content of the voltage and current waveforms produced by the Producer's generator(s) shall be restricted to levels which will not cause interference or equipment operating problems for BCH, its customers or telephone communication circuits. Generator auxiliary equipment such as variable speed motor drives are much more likely to introduce harmonics into the distribution system than synchronous generators:

The introduction of harmonics in the BCH system shall not exceed the following:

(a) in order to compare levels of harmonic distortion in a power system, the Total Harmonic Distortion (THD) is used, defined as follows for current or voltage:

$$\left(\frac{\text{sum of squares of RMS magnitudes of all harmonic voltages }^*}{\text{square of RMS magnitude of the fundamental 60 Hz voltage}}\right)^{1/2} \times 100\%$$

* excludes the fundamental

BCH follows the IEEE Standard 519-1992, "IEEE Recommended Practices and Requirements for Harmonic Control in Electric Power Systems". Section 10 describes the current distortion limits that apply to individual consumers of electrical energy. Table 10.3 lists the current distortion limits for distribution systems 120 V through 69,000 V.

Consumers with power generation equipment must limit Total Demand Distortion (TDD) to 5.0% at the point of common coupling (within an industrial plant, the point between the non-linear load and other loads). TDD is harmonic current distortion in % of maximum demand load current over 15 or 30 minutes. Section 11 in IEEE 519 describes the quality of electrical power that the utility should provide the consumer. Table 11.1 lists a maximum total harmonic voltage distortion of 5.0% at the point of common coupling for systems 69 kV and below, with individual harmonic voltage distortion not to exceed 3.0%.

(b) harmonic-caused telephone interference problems have limited correlation with **I•**T products. This guide imposes no design limits on the calculated **I•**T values. **I•**T denotes the inductive influence expressed as the product of the RMS value of the current waveform (I) and the telephone influence factor (TIF) of the current waveform (T). TIF was developed to account for the frequency response characteristics of the coupling between the powerline and the telephone lines, the telephone system, and the human ear.

Telephone interference is, in many cases, caused by residual (zero sequence) harmonic currents. Also, indirect harmonic telephone interference may be caused by the interaction of non-residual harmonic currents with the supply system equipment. Since the indirect interference is impossible to predict in most cases, applying **I•**T limits, balanced or residual, serves little useful purpose.

Although no design limits are imposed, harmonic-telephone interference can be checked using measurement techniques. Telephone interference due to harmonics involves three major factors: the existence of the source of interference, the coupling between the source and telephone cable, and the susceptibility of telephone equipment. The **I•**T product only addresses the problem of the source of interference. The complexity of harmonic-telephone interference makes it impossible to accurately calculate the interference level with all three factors included. However, telephone interference measurements can be performed on any telephone set vulnerable to generator-induced harmonics, using indices adopted by the telecommunication industry. These measurements are the noise to ground and cable balance.

3.6 Phase Current and Phase Voltage Unbalance

Most distribution feeders supply mainly single-phase loads and consequently all three phases are never equally loaded. Phase current unbalance of 10-20% and phase voltage unbalance up to 2-3% are considered "normal" supply conditions for distribution circuits.

Voltage unbalance in % is defined as

$$100 \times \frac{\text{(max deviation of any of the 3-phase voltages from average phase voltage)}}{\text{(average phase voltage)}}$$

ANSI Standard C84.1-1989, Electric Power Systems and Equipment - Voltage Ratings (60 Hertz), recommends that the utility supply be designed and operated so voltage unbalance not exceed 3% at the utility revenue meter under no-load conditions. The voltage measurements are phase-to-phase, not phase-to-neutral.

The impact of 1-phase generators on distribution system phase current or phase voltage unbalance may limit the kW rating of 1-phase generation connected to Hydro's system.

Unbalanced phase voltages generated by the Producer's generator(s) may be harmful to the BCH customers. Of particular concern is negative sequence voltage and the resulting effect, particularly on rotating generators and motors connected to the system. Under normal operating conditions, the negative sequence voltage from 3-phase Producers shall not exceed 1.5% at the point of delivery, or such limit as agreed to by BCH.

4.0 GENERATOR REQUIREMENTS

The Producer's generator(s) connected to BCH must meet the following requirements:

4.1 Canadian Electrical Code

Generators connected in parallel with the BCH distribution system must conform to the Canadian Electrical Code Part 1 (CSA C22.1-98) and BC Amendments where applicable:

- Section 50: Solar Photovoltaic Systems
- Section 84: Interconnection of Electric Power Production Sources

4.2 Excitation System

For synchronous generators rated 1 MW and up, the excitation system is required to be a high gain, fast responding system. The excitation system is to be capable of continuous operation at supply voltages ranging from 80% to 110%.

4.3 Voltage Regulator

A voltage regulator is required to adjust the generator terminal voltage and maintain desired reactive power flow during normal operation. This can be achieved at a small Producer by manually adjusting the generator field current within the range 0.5-1.25 pu either locally or by remote control. For large installations, automatic voltage control is typically provided by a system that can vary the field current up to about 2.5 pu based on 1-phase feedback of the generator output voltage.

Hydroelectric generators may undergo large speed changes during a sudden load change. The voltage regulators for these generators must maintain a linear characteristic with voltage variations restricted to less than 5% when machine speed varies from minimum to maximum anticipated value.

The generator shall be capable of maintaining its voltage under steady state conditions without hunting and within +/-0.5% of any voltage level between 95 and 105 percent of the rated generator voltage.

4.4 Automatic Synchronizer

Induction generators do not require synchronization since there is no generated voltage prior to connecting to BCH. The generator speed is brought to within 0.5% of its rated value. These units may be started as induction motors using power from the BCH system provided that these units do not cause unacceptable voltage flicker on startup or on connect/disconnect.

For synchronous generators, an approved automatic synchronization device must be provided in all cases where the plant is to be operated unattended. If the plant is attended, the generator may be equipped with a manual synchronization device with relay supervision. The operator on site must have sufficient training to perform the function safely. Synchronization controls shall satisfy the following conditions:

(a) the generator speed should be matched to within 0.5% of its rated speed,
(b) the phase angle difference between the generator and BCH should be less than 20 degrees,
(c) the RMS voltage magnitude difference between the two systems should be less than 4% to avoid excessive currents,
(d) field current should not be applied until the generator speed is at least 85% of its nominal value.

The BCH Area Control Centre will generally require the Producer to contact the Control Centre before synchronization can take place, as per the Local Operating Order.

4.5 Voltage or Power Factor Control

Synchronous generators rated 500 kW and up shall be able to operate continuously at any power factor between 90% lagging (generating vars, overexcited) and 95% leading (absorbing vars, underexcited) at any voltage level within $\pm$ 5% of rated voltage. BCH studies may show that a lower power factor rating is required for the Producer's generator(s).

Synchronous generators rated 500 kW and up will generally be required to deliver reactive power to BCH at the point of interconnection, via:

- most common: maintaining a stable generator bus voltage by generating/absorbing reactive power as required, or
- less common: maintaining a specific power factor range from lagging to leading over a specified system voltage range. The reactive losses in the Producer's transformer must also be considered, since the transformer impedance reduces the reactive power available for export to BCH.

The determination of generator power factor range depends on the Producer's MW rating compared to the feeder's annual maximum/minimum load, the length of the feeder and the Producer's location, the effect of generator reactive power on system losses, and whether the generator is connected to a dedicated or non-dedicated feeder. BCH will determine the Producer's power factor range by considering a fixed MW output then plotting the Mvar flow through the interconnection point versus system pu voltage over its expected operating voltage range. While some of the Producer's data required for these plots may not be firm at the early stage of design, preliminary information will give a good estimate of an appropriate range for reactive power flow with the proposed generating equipment.

Induction generators have no inherent capability to control reactive power. Induction generators rated 50 kW and up shall provide shunt capacitor compensation to maintain generator output power factor at 90% or better at full rated power. If the selected shunt capacitor ratings exceed the limit for self-excitation of the generator, provision must be made to switch out the capacitors on sudden loss of load such as by capacitor overvoltage relay or series resistor, to prevent sustained self-excitation and unpredictable voltage and frequency excursions.

4.6 <u>Speed Governors</u>

Prime movers for synchronous generators must be equipped with an automatic speed control governor, except as noted is sections 4.6.1 & 4.6.2 below. A droop characteristic of 5% is typically used when speed governors are employed. Their control characteristics should be selected to:

(a) prevent oscillations of the generator load angle during normal system operation,
(b) maintain frequency within acceptable limits for the auxiliary loads when the Producer becomes isolated from BCH during system faults,
(c) prevent damaging overspeeds on full load rejection.

Regardless of whether governors are used, the prime mover output power must be controlled to allow manual control while loading or unloading the generator. This will be some form of gate control in a hydroelectric plant, and regulation of fuel or stream input by a throttle on thermal generating units.

4.6.1 <u>Hydraulic Turbines</u>

Hydraulic turbines used in small plants (rating < 200 kW) may not be equipped with conventional governors for speed control, provided they are not susceptible to damage due to over or underspeed operation when isolated from the BCH feeder, but may have only overspeed protection sensors. Provision must be made for rapid disconnection from BCH during abnormal frequency conditions such as generator islanding.

For hydraulic turbines equipped with a conventional governor, the overspeed following load rejection depends on the reaction time of the governor-gate system and may be in the order of 120-160% of normal speed, particularly during generator separation from BCH.

4.6.2 <u>Steam Turbines</u>

Speed governors are usually necessary when thermal prime movers are used since station auxiliary equipment typically requires a power supply within relatively narrow frequency limits. The speed for steam turbo alternators is governed by controlling the flow of steam. Typical steam turbines in distribution-class plants can withstand speed variations of about 1-2% with wider excursions risking blade damage. Turbo alternators are equipped with mechanical overspeed trip controls, as a backup to the on-line speed governors.

Overfrequency in the BCH hydroelectric system may cause overspeed at the generators and result in turbine damage. The Producer should protect against overfrequency conditions via overfrequency relays.

4.7 Power Frequency Requirements

The system frequency is 60 Hertz and is maintained within a very tight tolerance (± 0.1 Hertz) under normal system operation. The Producer's generator(s) shall be designed for 60 Hz operation and maintain their steady-state frequency to BCH at 60 +/- 0.1 Hz.

4.8 WSCC Reliability Requirements

Individual synchronous machines rated 10 MVA and up will be subject to the requirements of the WSCC (Western System Coordinating Council) Reliability Management System, independent of the operating voltage at the Point of Connection to BCH .

5.0 STATION EQUIPMENT REQUIREMENTS

5.1 Surge Arresters

Surge arresters are recommended for protection of station equipment such as transformers and circuit breakers, and applied as close as possible to the equipment to be protected. Where they are applied, BCH revenue metering equipment shall be located close enough to the arrester to be effectively protected.

Voltage ratings are as follows:

BCH System Voltage Rating	Arrester Rating
12 kV	9 kV
25 kV	18 kV
35 kV	27 kV

5.2 Isolation Equipment

The Producer shall provide a loadbreak gang-operated isolating switch with a visible break at the point of delivery to BCH, accessible to BCH at all times and capable of being secured by a standard BCH padlock. In those cases where the point of delivery is some distance from the generating plant, the Producer would install a second isolating switch at the entrance equipment, interlocked with the entrance breaker. Disconnection interlocks shall be in accordance with the latest Canadian Electrical Code isolation requirements.

See also Section 6.5.

5.3 Transformers

A generator transformer is a stepup transformer which transforms generated voltage to a higher voltage for connection to a distribution feeder. The transformer connection selected will affect BCH protective systems in terms of ground fault contribution, harmonic current flow and the use of single-phase or three-phase protection devices. Producers must submit their transformer connection proposal to BCH for approval before placing an order for purchase.

BCH recommends that transformers have off-load taps on the primary side with a minimum range of 2 x 2.5% above and below nominal voltage.

BCH will define the high voltage and connection type for the Producer's transformer. The preferred transformer connection is grounded-wye on the BCH side and delta on the generator side. This connection offers more advantages than disadvantages. An exception to this connection method may be granted in some cases, e.g. a BCH customer wishes to operate generation in parallel with the BCH supply system where a customer entrance transformer is already in place. A common primary service connection to these customer substations is HV delta/grounded wye. One difficulty with this connection is Producer provision of BCH feeder SLG fault protection when customer generation is in parallel with the BCH supply. Remedies to protect L-N connected customer equipment, surge arresters and BCH equipment from temporary or permanent L-N overvoltage upon opening of the BCH feeder CB are:

(a) Producer installs a 3-phase grounding transformer, with CT(s), on the HV delta side, or
(b) Producer installs a 59N ground fault overvoltage relay (zero sequence voltage relay) to the HV side via 3 VT's wired with grounded-wye primary and broken delta secondary. However, this alternative has a risk that the generator can still supply an ungrounded system with damaging L-N overvoltages if the BCH protection clears the fault but the fault extinguishes before the Producer's protection operates.

Although grounded-wye on the BCH side and delta on the generator side has a number of advantages for both BCH and the Producer, the following points must be considered:

(a) zero sequence currents originating in the BCH system will cause circulating currents in the delta winding of the transformer and their magnitude should be considered when determining transformer rating,

(b) the ground fault relays for the Producer's entrance CB must be connected to CT's on the BCH side of the transformer, since zero sequence current flows only in the primary side circuit,

(c) a line-ground fault near the Producer results in a reduction in ground current to the BCH ground over-current relay. BCH generally requires the Producer to install a neutral reactor between transformer primary star point and earth, for generators rated 1 MW and up, to recover ground return current to the BCH ground overcurrent relay. This requires that the power transformer windings be insulated for line-to-line voltage at the neutral. The incoming BCH neutral conductor is connected to the earth side of this neutral reactor, and the reactor typically has an ohmic value of 1.0-1.5 times transformer zero sequence reactance. Impedance grounding also lowers transformer inrush current at the generator transformer. BCH does not accept resistor grounding because it marginally increases system losses, results in higher overvoltage on unfaulted phases and heat must be dissipated when ground current flows,

(d) if a ground fault occurs on the Producer side of the transformer when the generator is not operating, no fault current flows on either side of the transformer and ground fault relays will not detect the fault. The remedy is voltage sensing relays on the Producer side of the transformer.

5.4 Station Grounding

The equipment and station shall be grounded in accordance with the latest Canadian Electrical Code. Ground conductor size, ground potential rise and step and touch potential calculations shall be based on ultimate line-to-ground short circuit currents as specified by BCH for high voltage faults, unless exceeded by the Producer’s low voltage short circuit currents.

6.0 PRIMARY DISTRIBUTION LINE REQUIREMENTS

6.1 Primary Voltage Distribution Line

The primary voltage distribution line for connecting the larger Producers (typically 1 MW and up) to the BCH distribution system must be designed and constructed according to BCH standards.

B.C. Hydro's primary overhead distribution is a three-phase four-wire multi-grounded common neutral radial system.

Most of the overhead system is wood pole construction. For 1-phase primary operation, the phase conductor is on a poletop pin at the top of the pole and the neutral conductor is on the pole approximately 1.8 to 2.6 m below. For 3-phase primary operation, two phase conductors are 6 ft apart on a 7 ft crossarm near the top of pole, one phase conductor is on the poletop pin and the neutral conductor is approximately 1.8 to 2.6 m below. The neutral conductor may be located on the crossarm with the phase conductors where it is difficult to achieve adequate ground clearance.

BCH feeders have a nominal current rating of 300 A.

Urban feeders are typically current-limited and have 3-phase gang-operated line switches, fused 1-phase primary laterals and may have fixed and/or switched shunt capacitors.

Rural feeders are typically voltage-limited and have fused 1-phase primary laterals. They may have 3-phase gang-operated line switches, reclosers, sectionalizers, mainline fuses, voltage regulators, and fixed and/or switched shunt capacitors.

6.2 Insulation

BCH recommends that the BIL of the Producer’s entrance equipment be compatible with the BIL of the BCH system, namely:
(i) 65 kV BIL on the 4.16 kV system,
(ii) 95 kV BIL on the 12.5 kV system,
(iii) 125 kV BIL on the 25 kV system,
(iv) 150 kV BIL on the 34.5 kV system.

6.3 Operating Voltage

The range of acceptable voltage at the consumers' service entrance is listed in Section 3.3, for steady-state normal operation. This normal range of 110-125 V at residential consumers' service entrances implies an acceptable range of about 117-127 V in the primary conductor, allowing for voltage drop in the distribution transformer, secondaries and service conductor.

6.4 Primary Phase Conductors

The type and size of the phase conductors are governed by the physical and thermal loading the conductors must carry and the maximum design conductor temperature. Primary phase conductors will generally be selected to minimize long term line losses, and thus may have an ampere rating above the maximum Producer MW export level. Standard trunkline conductors are 336 kCM ASC and 266.8 kCM ACSR, with a 1/0 ACSR common neutral conductor.

6.5 Point of Connection to B.C. Hydro System

The distribution line for incorporating the generation development could be connected to the BCH system at either a distribution substation via a dedicated line or connected directly to a BCH distribution feeder with BCH customer load.

All Producers, whether connected at primary or secondary voltage, must provide a disconnect device to permit isolating the generation from the BCH distribution system. This device is normally a switch located at the point of connection to BCH.

Terms and conditions covering the control and operation of this disconnect device are covered by the BCH Local Operating Order prepared by the BCH Area Control Centre for signature by the Producer's operator.

The disconnect device must be a load break gang-operated disconnect switch rated for the voltage and current requirements of the particular development, be operable under all weather conditions of the area and lockable in both the open and closed positions by a standard BCH padlock. The switch must be able to make and break the generator transformer magnetizing current. Load break switches shall comply with CSA Standard C22.2 No. 193-M1983 (R1992), "High Voltage Full-Load Interrupter Switches". If the loadbreak switch is operated by an automatic shunt trip, the information of power source for tripping must be provided.

7.0 SERVICE ENTRANCE PROTECTION REQUIREMENTS

BCH employs overcurrent and overvoltage devices in the primary distribution system. The two main types of overcurrent devices used are fuses and reclosers. Overcurrent devices, when properly coordinated, reduce outages caused by temporary faults and minimize the number of customers affected by a permanent fault.

Surge arresters may be used to protect distribution lines from overvoltages caused by lightning surges, line-to-ground faults and switching operations.

Overall circuit protection is provided by a circuit breaker or a recloser in the feeder position at the BCH distribution substation.

Distribution feeder information can be obtained from the Distribution Engineering & Planning department, including:
(a) feeder maximum and minimum fault levels at the proposed point of interconnection,
(b) details of feeder load and capacity,
(c) the voltage regulator setpoint, bandwidth and time delay at the BCH substation,
(d) details on the setting, sequence of operation and other characteristics of feeder breakers, line reclosers and fuses,
(e) feeder reliability records.

7.1 General

BCH promotes the following three fundamental protection considerations for the Producer's installation:

(a) the Producer shall provide protection with adequate sensitivity for all electrical faults on its premises, from present to ultimate levels, which will coordinate with BCH requirements. This protection is generally referred to as "entrance protection". In this document, coordination is defined as either:

(i) fully selective clearing - the Producer's protection shall clear all faults in the generating plant before BCH relaying initiates tripping for such faults, or
(ii) simultaneous clearing - the Producer's protection shall clear all faults in the generating plant coincidentally with BCH clearing of such faults.

Unless system conditions on the BCH system dictate otherwise, the former [item i] will apply for Producer installations.

(b) additional protection shall be provided to detect BCH distribution line faults. This protection is referred to as Producer "distribution line protection". The equipment shall be as fast and as sensitive as required to interrupt faults within a time specified by BCH. For 3-phase generators greater than 40 kW, a ground fault sensing scheme which detects BCH ground faults and trips the service entrance circuit breaker shall be provided,

(c) the Producer's equipment shall be rated to carry and interrupt the faults levels that are or will be available at his location - this includes the ultimate fault currents specified by BCH. The Producer's equipment includes all protection equipment forming the entrance and distribution line protection: current transformers, potential transformers, secondary cabling, dc system/battery charger, switchboard wiring and protective relays.

Producer service entrance interrupters connected to BCH at primary distribution voltage shall have the following minimum interrupting capabilities:

Type of 3-Phase Service	Circuit Breakers & Reclosers Symmetrical MV.A	Fuses Asymmetrical RMS Amperes	Fuses Symmetric RMS Amperes
4.16 kV, 4-Wire	50	12,000	7,500
12.5 kV, 4-Wire	250	20,000*	11,500*
25 kV, 4-Wire	500	20,000*	11,500*
34.5 kV, 4-wire	300	9,000	5,000

* On outdoor pole top installations, the Producer may install 12,000 A asymmetric cutouts (8000 A symmetric).

The following additional general requirements should be noted:

(a) power quality protection for BCH customer loads is required for all generating plants: undervoltage, overvoltage, underfrequency, overfrequency,

(b) BCH metering equipment shall be included in the entrance protection zone, on the Producer's side of the entrance protection device,

(c) distribution feeders operate with varying unbalanced phase current. The Producer's equipment may be subjected to negative sequence current due to negative sequence unbalance in the distribution system. The Producer is therefore encouraged to provide negative sequence (current unbalance) protection (46) for generators,

(d) during emergencies or during abnormal operating situations on the utility system, the Producer may experience undervoltage conditions. Producers are encouraged to provide timed undervoltage tripping (27) to protect their equipment,

(e) some BCH distribution feeders are equipped with automatic and/or supervisory reclosing facilities at the substation feeder breaker, and some rural feeders have automatic reclosers out in the feeder. Out-of-phase switching can result in inrush currents up to 10 times the generator current rating. Producers shall provide generator protection for the possibility of an out-of-synchronism reclose from BCH line reclosers, automatic reclosing breakers and supervisory reclose of feeder breakers. Alternatively, it may be possible for BCH to disconnect automatic feeder breaker reclosing and add voltage supervision to prevent out-of-synchronism reclose by line reclosers and prevent supervisory reclose of substation feeder breakers,

(f) rural feeders may have fuses, reclosers and/or sectionalizers in the 3-phase mainline. The generator shall also be protected against possible single phasing on the feeder, which can occur in both rural and urban feeders,

(g) the primary and secondary side Producer protection devices must withstand the maximum transformer inrush current during energization,

(h) when the Producer installs surge arresters, they shall be installed as close as possible to the equipment they are protecting,

(i) care should be taken in designing preventative and corrective interlock systems that all emergencies and contingencies can be dealt with.

7.2 Protection with Relays and Circuit Breaker

Plants rated 200 kW and up must provide an entrance circuit breaker (CB) or recloser for protection tripping. An exception may be granted in certain cases, such as where a generator is added to an existing customer load facility which already has a main transformer and entrance fuses. The CB shall have an interrupting rating equal to or higher than the ultimate fault duty determined by BCH. The circuit breaker must also be capable of tripping the capacitive load of the incoming line and out-of-phase opening for unintentional reclose by BCH.

7.2.1 Current Transformers

(a) BCH requires that the current transformer be located at the source side of its associated circuit breaker but at the load side of the disconnect switch. Exceptions may be granted on request. If a draw-out type circuit breaker is used and the gang-operated disconnect switch is omitted, the relay CT can be located on the load side of the Producer's circuit breaker,

(b) current transformers shall have mechanical and thermal ratings adequate for the expected fault duty. For low ratio CT's, special designs may have to be ordered to achieve an adequate mechanical rating,

(c) where current transformers and relays are used to provide overload protection in conjunction with fuses, the fuses must limit the prospective short-circuit current to the mechanical rating of the current transformer,

(d) the current transformers shall be adequately rated to operate the relays and the breaker trip coil if an ac trip scheme is adopted. The success of the ac trip scheme depends primarily on the capability of the CT to provide enough energy transfer to the trip mechanism of the breaker when primary fault current is flowing under all practical conditions. Saturation of the CT, with high impedance secondary circuits, can be experienced not only due to the dc component of the fault current, but also due to a high magnitude of ac symmetrical fault current. The secondary current through the trip coil under such conditions cannot always be assumed to be able to activate the breaker trip mechanism.

7.2.2 Relays

BCH does not require the Producer's service entrance protective relays to be tested and approved by BCH, provided that the relays meet the minimum requirements specified in IEEE C37.90, "Standard for Relays and Relay Systems Associated with Electrical Power Apparatus", latest edition. BCH reserves the right to require that the protective relays be tested for acceptability by an independent test facility. Utility grade, rather than industrial grade, protective relays are required for plants rated 500 kW and up.

(a) the overcurrent relays may be arranged as three-phase relays or as two-phase relays and one ground relay. The latter arrangement will be required for coordination with BCH ground relays for larger installations and is generally preferable. A minimum time clearance of 0.4 seconds between the characteristics of the Producer's relay and the BCH feeder relay for maximum fault current at the Producer's installation shall be maintained,

(b) differential relay protection alone on the Producer's main breaker is not acceptable. It must be accompanied with overload protection,

(c) certain large projects may require special relays such as:
- some form of phase distance relaying looking onto the BCH feeder from the Producer,
- torque-controlled overcurrent relays (by means of undervoltage detection) to detect phase-phase faults far from the Producer,
- out-of-step relaying,

(d) relays employed shall be equipped with a test switch to provide isolation for CT's, VT's and the trip bus and to facilitate current injection tests,

(e) for those plants where the T&D Interconnection Agreement provides for Producer islanding of BCH customer load, automatic separation in order to commence isolated operation may require special devices such as a remote terminal unit (RTU) and appropriate communication media.

The typical relays for plants rated 500 kW and up are as follows. Each project is reviewed individually:

Protection	Typcial Settings
Undervoltage (27)	instantaneous and timed; pickup at 90% of nominal voltage, with a 1 second time delay; instantaneous undervoltage shall not be less than 60% of nominal voltage; voltage sensing on each phase
Overvoltage (59)	instantaneous and timed; pickup at 110% of nominal voltage, with a 1 second time delay; instantaneous overvoltage shall not exceed 140% of nominal voltage; voltage sensing on each phase
Underfrequency (81U)	pickup at 59.5 Hz with a 0.5 second time delay
Overfrequency (81O)	pickup at 60.5 Hz with a 0.5 second time delay
Overcurrent (50, 51)	phase and ground instantaneous and timed settings to coordinate with local BCH protection
Transformer differential (87T)	settings are site-specific
Voltage unbalance (47)	pickup at 7% phase voltage unbalance, with a 1 second time delay; voltage sensing on each phase
Current unbalance (46)	pickup at 10% phase current unbalance, with a 1 second time delay

Reverse power (32U)	detects excess power to BCH during island condition; settings are site-specific
Reverse power (32G)	protects turbine from damage due to motoring action of generator; settings are site-specific
Synchronism-check (25)	prevent breaker closure if slip frequency exceeds 0.25 Hz or phase angle exceeds 20 degrees
Battery/DC Undervoltage	pickup if dc voltage falls below 110% of the minimum reliable operating level for any device
Loss of field (40)	pickup for total or partial loss of generator field current, with a 0.5 second time delay

If the under/over voltage and under/over frequency relay settings result in too many nuisance trips, it may be necessary to use more elaborate relaying such as rate of change of frequency, change of reactive power or voltage-vector magnitude and phase.

7.2.3 Circuit Breakers

Circuit breaker selection considers continuous current, voltage, fault interruption and out-of-phase switching, interrupting time, capacitive switching current, low temperature operations and proximity to transformers.

Circuit breakers shall have a blade opening time of not more than eight cycles. Circuit breakers may be equipped with either an ac trip coil or dc voltage shunt trip coil. If the latter is applicable the Producer shall be responsible for adequate maintenance of its battery supply. If a stored energy voltage trip scheme is applied, such as a capacitor trip, the voltage supply for charging the capacitors must come from the source side of its associated circuit breaker.

See Section 7.5 for requirements to provide a secure breaker tripping power source.

An approved single shot recloser may be acceptable as a circuit interrupter.

7.3 Protection with Fuses and Loadbreak Switch

Fuses are generally acceptable for entrance protection for plants rated 200 kW or less.

7.3.1 Fuse Size

Fuses shall have time-current characteristics that will coordinate with BCH service fuses.

BCH service fuses up to 100 A type T may be installed ahead of the service cable for an underground (U/G) primary dip connection. In areas such as downtown Vancouver where services are provided direct from substation feeders through underground cable at primary potential, there will be no BCH service fuses. For overhead connection, BCH service fuses up to 100 A type T may be installed on the branch tap ahead of the Producer's disconnect switch.

For fused Producer installations where the BCH service fuses do not exist, such as on U/G dual radial or U/G loop primary connections, Producer fuses may have time-current characteristics up to 100 T.

It is not feasible to prepare a table of fuse sizes for each Producer transformer size, but the following criteria should serve as a guide:

(a) the fuse shall be sized as small as possible and conforms with the latest Canadian Electric Code and the B.C. Amendments,
(b) it shall withstand magnetizing inrush current. This varies from 8 to 12 times the rated current of oil filled transformers for 0.1 to 0.2 seconds. The transformer design greatly affects the magnitude of the maximum inrush current,
(c) the fuse must coordinate with the short time loading curve and the damage curve for the transformer,
(d) as a rule-of-thumb, the continuous current rating is 150-200% of transformer nominal current rating,
(e) it shall coordinate with BCH service fuses,
(f) for faults in the distribution feeder, generator protection should coordinate with the Producer's entrance fuses,
(g) the fuses must blow and clear all faults in the transformer and cables connecting the transformer to the generator breakers, before the BCH protection device trips.

7.4 Generator Distribution Line Protection

Since the Producer contributes to faults on the BCH system, the Producer shall provide equipment to clear all phase and ground faults on the utility distribution line. The Producer shall provide breaker failure protection for plants rated 1 MW and up.

Single-phasing of the three-phase primary service to a Producer can occur due to broken conductors and/or protective equipment operation and the Producer shall take measures to protect its plant.

7.5 Batteries & DC Chargers

The IPP must ensure that the continuous dc supply voltage rating of any relay or its associated power supply is not exceeded due to sustained overvoltages on the dc supply bus. Examples of conditions resulting in high, sustained overvoltages are battery chargers at the equalize setting, or battery chargers connected to the dc supply bus without the station batteries (not a recommended practice) or battery chargers set in the constant current charging mode.

If there is any possibility that the dc rating of a relay will be exceeded, then a passive voltage regulator of suitable rating shall be applied to each relay to limit the dc voltage to within the relay's dc rating. Dual station batteries are not required for power protection and control equipment. A single dc supply is acceptable.

DC system requirements are:

1. protection systems which are intended to back each other up must be supplied from dc circuits which are physically separated and separately protected. Also, power circuit breaker control circuits must be supplied from dedicated and independently protected dc circuits,

2. one undervoltage relay (set at least 5 V dc above the minimum acceptable voltage to operate the circuit breaker and associated protection and control circuitry) will be provided. The setting shall be adjustable in case the dc requirements change, for example if equipment is added or replaced at a later date. Operation of this relay is to shut down the generator and open the HV circuit breaker to disconnect the IPP from BC Hydro when the battery voltage dips to an unacceptably low level. A time delay is recommended for this trip initiation to override temporary voltage dips. This time delay shall not exceed 1 minute. This undervoltage tripping function is not required if the IPP generating facility is manned 24 hours a day,
3. one undervoltage relay, with time delay, to provide an alarm for battery charger failure or loss of ac supply. The voltage setting and time delay shall be coordinated with the undervoltage tripping function described above.

8.0 CONTROL AND COMMUNICATION

8.1 General

A Local Operating Order will be prepared by the BCH local Area Control Centre, for signature by the Producer. This document defines such items as operating responsibility for BCH and the Producer's equipment, method of obtaining clearances, personnel contact names and phone numbers for BCH and the Producer, BCH reclosing procedure and Producer connect/disconnect procedure.

The Producer shall maintain an operating log at each generating facility indicating changes in operating status, maintenance outages, trip indications or other abnormal conditions found upon inspection. For this reason, protective relays should be equipped with targets or indicators. For larger generation installations, BCH may require that protective devices be connected to an annunciator or events recorder so that it will be possible to determine which devices caused a trip.

As a result of the connection of a Producer to the BCH system, control and communications facilities including communications media, may be necessary for the safe and efficient operation of the BCH power system within acceptable parameter limits. These facilities can include requirements for power system protection, power system operation, remote revenue metering and the safety of personnel. Due to the large number of variables involved, the requirements for each Producer connection will be determined individually when the Producer's proposal is reviewed. Facilities may be required at the Producer's premises and at BCH locations such as substation and Area Control Centres.

BCH may require the Producer to provide control and communication equipment to allow automatic transfer tripping of the Producer's entrance circuit breaker upon opening of the BCH substation feeder breaker or line recloser.

The BCH intention is to implement only the minimum facilities that are required. The typical minimum communication is voice communication from the BCH Area Control Centre to the plant's operator.

8.2 Communications Media

Communications media alternatives between the Producer and BCH, and within the BCH system may include: dedicated or leased wire line circuits (with appropriate entrance protection), powerline carrier, microwave radio, UHF/VHF radio or fibre optics. When two-way communications media is required, full duplex (4 wire) circuits will generally be used, except for standard voice telephone circuits on wire line.

Communications media may be required for remote interrogation of revenue metering, generator data acquisition in real time or delayed time, or power quality monitoring on the Producer's premises.

9.0 REVENUE METERING REQUIREMENTS

9.1 General

The T&D Interconnection Agreement will specify that either BCH or the Producer will supply the metering equipment. In the latter case, the Producer has total responsibility for the supply, installation, maintenance and reading of all revenue metering equipment. BCH must approve this metering before purchase. Suitable metering equipment such as meter, instrument transformers, test block, wiring, and auxiliary equipment may be available for purchase from BCH.

BCH may specify a dedicated feeder between the Producer and the local BCH substation for very large plants. In this case, the BCH metering may be located at the BCH distribution substation.

Revenue metering installations supplied by BCH and/or the Producer, for billing purposes, must be in accordance with the requirements set out in the Electricity and Gas Inspection Act and associated Federal Government Regulations. One set of revenue metering equipment shall be provided, maintained and installed by BCH or the Producer in accordance with these Regulations and BCH Metering Standards. Duplicate revenue metering equipment, provided by the Producer at its option, shall also be in accordance with these Regulations and BCH Standards. These revenue metering requirements include the following:

(a) meters, current transformers, voltage transformers, voltage transformers and auxiliary metering equipment must be covered by Approval of Type Notices issued by Industry Canada,
(b) billing meters must be verified and sealed by an accredited meter verifier, e.g. a Federal Government Inspector. Re-verification is also required on a periodic basis,
(c) metering installations are subject to periodic inspections by a Federal Government Inspector,
(d) suitable facilities, including test blocks, are required for these inspections,
(e) where instrument transformers are used, all secondary wiring is to be colour coded, preferably in accordance with BCH Standards. If other coding is proposed, it is to be submitted for BCH approval prior to installation.

9.2 Mandatory Requirements

9.2.1 Revenue Metering Equipment

BCH or the Producer, according to the T&D Interconnection Agreement, shall supply, install and maintain one set of revenue metering equipment consisting of any necessary current transformers, voltage transformers, test blocks, secondary wiring as well as a bi-directional meter capable of data recording and remote interrogation, compatible with current BCH requirements. A telephone line is required in order to remotely interrogate the meter.

9.2.2 Revenue Metering System

The revenue metering configuration shall be 3-element metering for 3-phase 4-wire grounded-wye systems. The metering voltage transformer connections are A phase to neutral, B phase to neutral and C phase to neutral. Metering current transformers are installed in A, B and C phases. The revenue metering configuration shall be 2 element metering for 3-phase 3-wire delta, ungrounded wye, or impedance neutral grounded wye systems, The metering voltage transformer connections are A phase to B phase and C phase to B phase. Metering current transformers are installed in A and C phases.

9.2.3 Power Quality Monitoring Equipment

BCH or the Producer may supply, install operate and maintain power quality monitoring equipment (with remote interrogation capability at 1200, 2400, 4800 and 9600 baud) which will monitor frequency, voltage and power factor drifting outside of preset limits. Where feasible, the revenue metering equipment and the power monitoring equipment will be an integral package.

9.2.4 Facilities Supplied by Producer

(a) mounting space (indoor in most cases) for equipment listed in Section 9.2.1 and 9.2.3 above,
(b) PVC rigid 1.5-inch conduits for CT and VT secondaries and 0.75 inch for telephone circuits required for remote interrogation of equipment listed in Section 9.2.1 and 9.2.3 above,
(c) the Producer shall supply the telephone circuit,
(d) all primary connections to CT's and VT's.

9.2.5 Drawings

The Producer shall supply to the Distribution Engineering & Planning department:
(a) five copies of electrical one-line diagram,
(b) five copies of drawings covering the proposed mounting facilities for meters, recorders and associated instrument transformers,
(c) Distribution Engineering & Planning will forward one copy of this information to the Revenue Metering Department at least 3 months prior to the in-service date.

9.3 Optional Requirements

For projects under 1 MW in nameplate capacity and which may not require time of day meter readings for billing purposes, the requirements listed under Section 9.2.1,9.2.3, and 9.4.1 will be at the discretion of BCH.

Considerations will include:
(a) incremental cost of remote interrogation equipment listed under Section 9.2.1, 9.2.3, and 9.4.1,
(b) availability of a telephone in the Producer's plant,
(c) cost of manual meter reading,
(d) requirements of the BCH Area Control Centre for the information available from the equipment in Section 9.2.3 above,
(e) project size.

9.4 Instrument Transformers

Current transformers and voltage transformers for revenue metering purposes shall be in accordance with CSA Standard CAN 3-C13-M83 (latest revision) and approved by Measurement Canada as noted above. General requirements include the following:

9.4.1 Accuracy

Voltage Class	CT Accuracy	VT Accuracy
600 Volt	0.3 B O.9	0.3 W and 0.6 X
15 kV (CT Ratio to 50/5A)	0.3 B O.9	0.3 W,X,Y,
15 kV (Higher Ratios)	0.3 B 1.8	0.3 W,X,Y,
25 kV (CT Ratio to 50/5A)	0.3 B 0.9	0.3 W,X,Y,
25 kV (Higher Ratios)	0.3 B 1.8	0.3 W,X,Y,

For Producers which require energy from BCH, wide ranging CT's are required. Accuracy is to be 0.15B0.1-B0.5 from 5% through rating factor.

9.4.2 Short Circuiting Device

Current transformers shall be fitted with a manually operated, self storing, means of shorting out the secondary winding and a means to prevent the shorting device from being closed when the CT is in service.

9.4.3 Short-Time Mechanical Current Rating

Current transformers with 15 and 25 kV voltage classifications shall have a minimum short-time mechanical current rating of 11,500 symmetrical RMS amperes.

9.4.4 Lightning Impulse Level (BIL)

Voltage Class	BIL
15 kV	110 kV
25 kV	150 kV

9.4.5 Units Containing Oil

The manufacturer shall guarantee that the oil is free from PCB contamination which is defined as the PCB content being less than 5 parts per million in any sample of oil.

9.4.6 Hardware

Chromated zinc hardware is recommended for CT's and VT's used for indoor or outdoor applications.

10.0 COMMISSIONING AND MAINTENANCE

10.1 General

The Producer shall have full responsibility for commissioning and periodic maintenance of the interconnection equipment.

Commissioning and maintenance must be performed by competent personnel from the Producer or a recognized service consultant. A copy of the commissioning and maintenance test reports signed by the person in charge shall be submitted to BCH.

Involvement of BCH personnel in commissioning, maintenance or trouble shooting does not mean, expressly or by implication, that all or any of the requirements of the law or good Engineering practices have been met by the Producer in its plant.

10.2 Commissioning

All electrical equipment in the Producer's system shall be certified and approved by the appropriate regulatory agency.

BCH must approve:

- entrance fuse rating,
- settings applied to overcurrent and power quality protective relays which operate the entrance and generator breaker, and the use of definite, inverse and instantaneous timing.

B.C. Hydro's interest in commissioning is to ensure that the generating installation does not pose safety hazards, meets the performance criteria of power quality and system reliability during normal and abnormal conditions, and does not adversely affect the operation of B.C. Hydro's power supply system. BCH shall be advised 10 days in advance of testing and may send a representative to witness the test.

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

(a) ratio test and polarity checks of current transformers and potential transformers, plus knee test for CT's,
(b) calibration check of pickup, reset and timing for each protective relay by injecting the appropriate ac quantities,
(c) trip test from the protective relays to circuit breakers,
(d) relay circuit load tests to verify correct connections with respect to the currents and voltages from the CT's and VT's,
(e) delivery to BCH of relay settings and test results, plus CT and VT test results,
(f) verification of the transformer neutral reactor's ohmic value and correct connection, where applicable.

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:

(a) doble test of high voltage equipment to ensure insulation adequacy,
(b) timing test of circuit breakers,
(c) integrity checks of auxiliary switches.

Prior to energization of the installation, BCH will require assurance acceptable to the local BCH Substation Manager assigned to the installation, that the Producer's interconnection equipment is as per agreement between BCH and the Producer, is mounted in suitable enclosure and is functional. BCH personnel may witness any part of the commissioning test, request additional testing or conduct their own testing to assure acceptance.

Deficiencies identified during commissioning must be corrected before parallel operation of generators with BCH commences.

BCH reserves the right to witness the Producer's commissioning and testing of the metering equipment. BCH also reserves the right to inspect and test any metering equipment prior to energization.

10.3 Periodic Maintenance

Maintenance for plant ratings 200 kW and up shall be scheduled jointly with BCH as follows:

(a) the Producer shall submit a maintenance plan to BCH on 1 January each year, or on a date set out in the T&D Interconnection Agreement,
(b) within 60 days BCH will either approve the plan or provide a new plan to the Producer,
(c) actual operating conditions may require changes to the plan and each party shall not unreasonably withhold approval of requested changes from the other party.

Periodic maintenance of protection equipment shall include but not be limited to calibration testing all protective relays and trip testing to circuit breaker at intervals of not more than 2 years. BCH reserves the right to inspect and test the protection at any time and to request the Producer to perform any necessary maintenance. Periodic maintenance of apparatus equipment shall be performed in accordance with the manufacturers' recommendations and/or accepted utility practice.

BCH reserves the right to test and inspect any metering equipment, and to be present during any inspection or testing of the Producer by the Federal Government.

11. REFERENCES

1. **BC Hydro Requirements for Customer's Primary Substations Supplied at 12 kV and 25 kV,** January 1996

2. CEA 128-D-767: **Connecting Small Generators to Utility Distribution Systems**, draft report March 1994

3. **Independent Generation of Electric Power**, David Stephen, Butterworth-Heinemann Ltd, 1994

4. IEEE Standard 519-1992, **IEEE Recommended Practices and Requirements for Harmonic Control in Electric Power Systems**, 1993

5. **Power Quality Reference Guide**, BC Hydro Customer Services, January 1990

6. **IEEE Guide for Interfacing Dispersed Storage and Generation Facilities with Electric Utility Systems**, ANSI/IEEE Std 1001-1988, February 1989

7. **Intertie Protection of Consumer-Owned Sources of Generation, 3 MVA or Less**, IEEE publication 88TH0224-6-PWR, 1988

8. CSA Standard CAN3-C235-83, **Preferred Voltage Levels for AC Systems 0 - 50,000 Volts**, 1983

Statement to B.C. Hydro Regarding Primary Voltage Service Entrance Equipment

APPENDIX 1

B.C. Hydro

The Customer, or representative, provide this Statement to B.C. Hydro knowing that B.C. Hydro intends to rely upon it.

B.C. Hydro may refuse to supply Electricity to the Customer or suspend or discontinue the supply if, in B.C. Hydro's judgment, the Equipment is not compatible with or suitable for the B.C. Hydro electrical system.

The judgment by B.C. Hydro of the Equipment shall not be construed by the Customer or others as an endorsement of the design or as a warranty by B.C. Hydro of the Equipment for the purposes of the Customer or others than B.C. Hydro.

Project	Location	Owner/Developer

Service U/G ☐ O/H ☐	At kV	Type of Service Equipment	Required Drawings:
Expected Service Date		O/H Structure ☐ Unit Sub. ☐	One-Line Drawing Number ____
		Outdoor ☐ Indoor ☐ Vault ☐	Site Plan Drawing Number ____
			Equipment Layout Drawing Number ____

Transformers:

Bank KVA	H.V. Winding - Check				L.V. Winding - Check				High Voltage Taps				On-load Tap Changer	Impedance
									Above Rated Volt.		Below Rated Volt.			
	Volts	Δ	Y	Y Grounded	Volts	Δ	Y	Y Grounded	No.	%	No.	%		____ % on bank KVA base (ONAN)
													± ____ %	

Service Entrance: (Complete I or II)

(I) Circuit Breaker:

Voltage Rating	Current Rating	Interrupting Rating	Clearing Time	Trip Coil	
KV	Amps	KA SYM RMS	Cycles	- Current Trip	Amps (ac)
				- Or Shunt Trip	Volts (dc)

(II) Fuse Protection: Either Load Break Switch, or Disconnect Switch Interlocked with Secondary Breaker.

(A) Switch (Specify Mounting): Pole ☐ Structure ☐ Cubicle ☐

Voltage Rating	Load Interrupting Rating	At	Limited Fault Interrupting Rating	At	Manufacturer (If Known)	CSA Approval
KV	Amps	% P.F.	Amps	% P.F.		Yes No

(B) Fusing

Manufacturer	Manufacturer Type Designation	Rated Continuous Current	Rated Maximum Voltage	Fuse Characteristics

Interconnection Protection:

Protection	Manufacturer	Type/Style	Timed Element Setting Range	Inst. Element Setting Range
Ground Overcurrent				
Phase Overcurrent				
☐ Over ☐ Under Voltage				
☐ Over ☐ Under Frequency				
Synchronizing Check				
Reverse Power				
Differential				
Under Frequency Load Shedding				

Are C.T.'s adequate to operate relays and current trip coils where applicable for all current magnitude from min. trip to max. fault duty?

☐ Yes ☐ No based on max. fault duty of ________ MVA

Metering:

Pole Metering	Yes ☐	No ☐
Vault or Indoor Unit Sub.	Yes ☐	No ☐
Outdoor or Unit Sub.	Yes ☐	No ☐

Estimated Max. Demand	
Initial	Future
________ KW	________ KW

Metered Voltage
Rate Schedule

Customer Generation:

- ☐ No Customer generation.
- ☐ Customer generation not parallel to B.C. Hydro supply, transfer switch type: ______________ .
- ☐ Customer generation parallel to B.C. Hydro supply but with no agreement to sell electricity to B.C. Hydro.
- ☐ Customer generation parallel to B.C. Hydro supply with intent to sell electricity to B.C. Hydro.

} If selected, complete Generators Section.

Generators:

Type	Energy Source	Manufacturer	Rated Output in KW	Rated Output Voltage	Power Factor	3Ø or 1Ø	Total Harmonic Content Current	Total Harmonic Content Voltage	Reactance in % Machine KVA Base Xd	Xd'	Xd''	Machine Inertia Constant H

Energy Source: 1. Hydraulic 2. Gas 3. Woodwaste 4. Diesel 5. Other: ____________

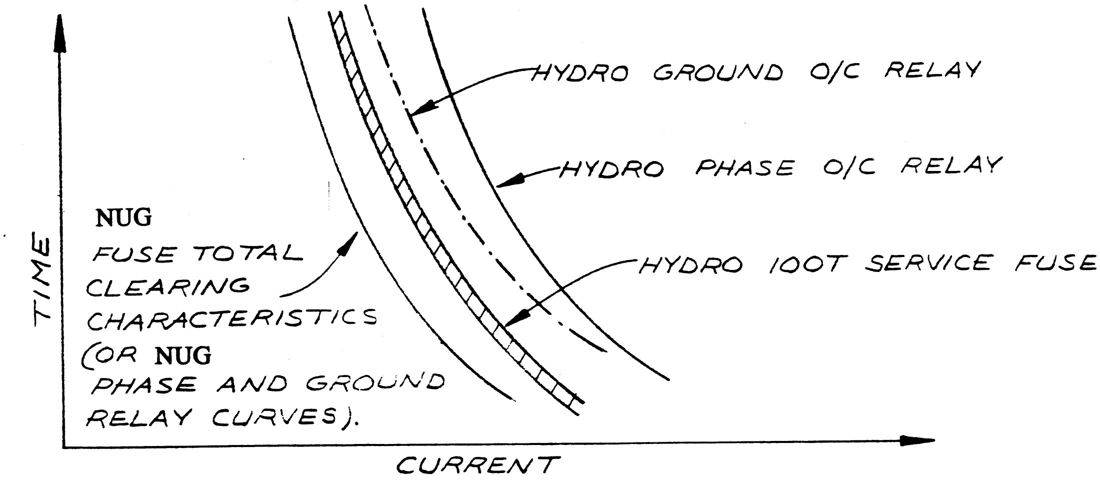
Type: 1. Synchronous Generator 2. Induction Generator 3. Other: ____________

If the above space is insufficient for all generators, please provide remaining generator information separately.

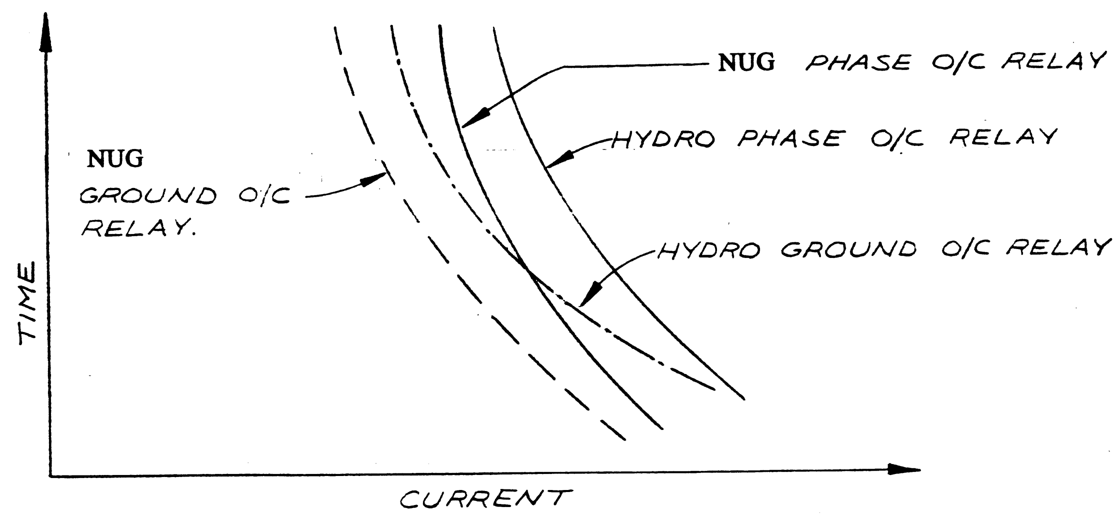
Seal of Professional Engineer

	B.C. Hydro
Company	
Signature	Received By
Date	Date

70340



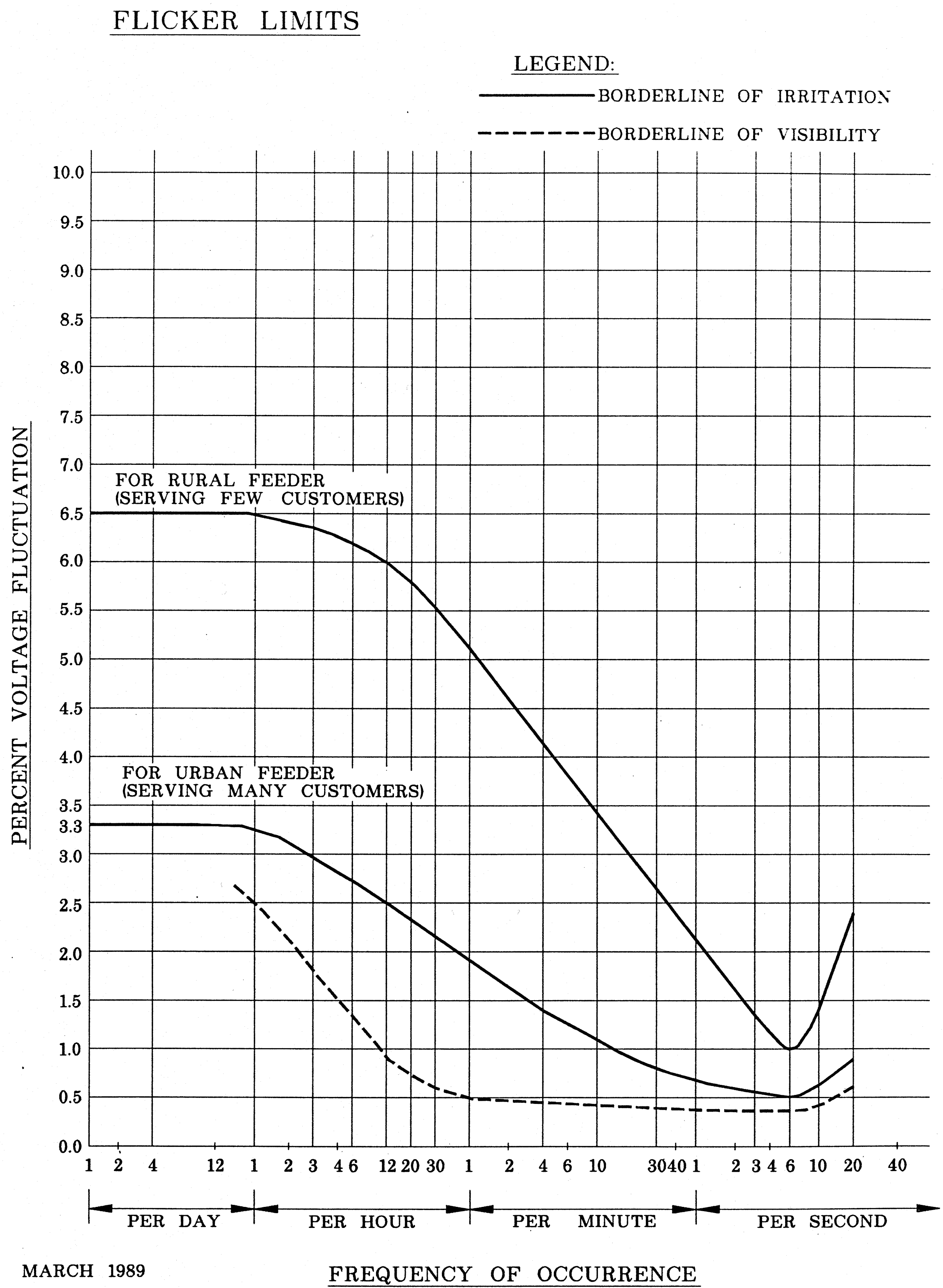
B.C. HYDRO SUPPLY WITH SERVICE FUSE



B.C. HYDRO SUPPLY WITHOUT SERVICE FUSE

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY						TYPICAL COORDINATION BETWEEN NUG SERVICE ENTRANCE PROTECTIVE DEVICES AND HYDRO TERMINAL EQUIPMENT
DES.	J. TAO	DATE		APPROVALS		
DES. CH.	J.T.	86-02-28				
DR.	J.W.					
DR. CH.						
SCALE:	N.T.S.		MICROFILMED			SHEET 1 OF 1 — DWG. NO. PG-DTS-A4 — R.0

APPENDIX 3


FLICKER LIMITS
LEGEND:
BORDERLINE OF IRRITATION
BORDERLINE OF VISIBILITY
PERCENT VOLTAGE FLUCTUATION
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.3
3.0
2.5
2.0
1.5
1.0
0.5
0.0
FOR RURAL FEEDER
(SERVING FEW CUSTOMERS)
FOR URBAN FEEDER
(SERVING MANY CUSTOMERS)
1 2 4 12 1 2 3 4 6 12 20 30 1 2 4 6 10 30 40 1 2 3 4 6 10 20 40
PER DAY
PER HOUR
PER MINUTE
PER SECOND
MARCH 1989
FREQUENCY OF OCCURRENCE