Technical Guideline For Interconnection Of Generators To The Distribution System

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EDTI acknowledges the use of other utility industry and industry committee developed documents as the framework and sources in producing this technical guideline.

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1. TERMS AND DEFINITIONS

The following terms and definitions are for your reference for the language used in this document and for use in any correspondence with EDTI.

This Term …	Is defined as …
Active Power	The time average of the instantaneous power over one period of the wave, expressed in watts. For sinusoidal quantities in a single-phase circuit, it is the product of the voltage, the current, and the cosine of the phase angle between them.
AECUC	Alberta Electrical and Communication Utility Code. Refer to website: www.safetycodes.ab.ca
AIES	Alberta Interconnected Electric System. This encompasses all transmission facilities and all electric distribution systems in Alberta that are interconnected, as defined in the Alberta Electric Utilities Act.
Alternating Current (AC)	An electric current that reverses direction at regularly recurring intervals of time and has alternating positive and negative values. In North America, the standard for alternating current is 60 complete cycles each second. Such electricity is said to have a frequency of 60 hertz.
Ampere	The unit of current flow of electricity, usually abbreviated as "amps”.
ANSI	American National Standards Institute. Refer to website: web.ansi.org
Anti-islanding	Designed to detect and disconnect from a stable unintended ‘island’ with matched load and generation. Reliance solely on under/over voltage and frequency trip is not considered sufficient to qualify as Anti-islanding.
Apparent Power	The product of the root-mean-square current and the root-mean-square voltage, expressed in volt amperes (VA). This term is used for alternating current circuits because current flow is not always in phase with voltage and hence volts times amperes does not necessarily give watts. It is made up of two components, active and reactive power.
Automatic Circuit Recloser (ACR)	A self-controlled device for automatically interrupting and reclosing an alternating current circuit with a predetermined sequence of opening and reclosing. EDTI uses these devices for over current protection on some distribution circuits.
AVR	Automatic Voltage Regulator means automatic control equipment that adjusts the generating unit excitation current to maintain voltage levels.
Capacity	In the electric power industry, capacity has two meanings: 1) System Capacity: The maximum power capability of a system. For example, a utility system might have a rated capacity of 5000 megawatts. 2) Equipment Capacity: The rated load-carrying capability of generating equipment or other electrical apparatus, expressed in kilovolt amperes (kVA) or kilowatts (kW).
CEC	The Canadian Standards Association's C22.1 Safety Standard for Electrical Installations Part 1, also known as the Canadian Electrical Code.
Certification Test	A test adopted by EDTI that verifies conformance of certain equipment with commission approved performance standards in order to be classified as certified equipment. Certification tests are normally performed by a nationally recognized testing laboratory such as the CSA or Underwriter's Laboratory.

This Term …	Is defined as …
Certified Equipment	Equipment used in a generating facility that has passed the Certification Test.
Closed Transition	A mode of operation in which the generator is operated in parallel with the distribution system for a brief period of time, to ensure that the load is maintained while transferring from the utility to the generator or vice versa.
Commissioning Test	A test performed during the commissioning of all or part of a generating facility system to achieve one or more of the following; verify specific aspects of its performance; calibrate its instrumentation; establish instrument or protective function set points.
CSA	Canadian Standards Association. Refer to website: www.csa.ca
Current	The flow of electricity in a conductor. Current is measured in amperes.
Direct Current (DC)	A unidirectional electric current in which the changes in value are either zero or so small that they may be neglected. The current supplied from a battery is direct current.
Distributed Generation (DG)	Electric generation facilities connected to a distribution system through the Point of Common Coupling (PCC). Distributed Generation is a subset of Distributed Resources (DR).
Distributed Resources (DR)	Sources of real electric power that are not directly connected to the bulk power transmission system. It includes both generators and energy storage technology.
Distribution System	Any facilities that operate at a nominal voltage of 25,000 volts or lower and that allow electric power to be delivered to a load, regardless of ownership.
EDTI	EPCOR Distribution Incorporated (EDTI), operating the electric distribution system in the city of Edmonton. Refer to website: www.epcor.ca
Electrical Energy	The quantity of electricity delivered over a period of time. The commonly used unit of electrical energy is the kilowatt hour (kWh).
Electrical Power	The rate of delivery of electrical energy and the most frequently used measure of capacity. The commonly used unit of electrical power is the kilowatt (kW).
Electromagnetic Interference (EMI)	Any electromagnetic disturbance that interrupts, obstructs, or otherwise degrades or limits the effective performance of a device, equipment or system.
Export Limiting	Designed to prevent the transfer of electrical energy above a certain value (the export limit), from the generating facility to EDTI's distribution system.
Ferroresonance	An oscillatory phenomenon caused by the interaction of system capacitance with the nonlinear inductance of a transformer, usually resulting in a high transient or sustained overvoltage.
Frequency	The number of cycles through which an alternating current passes in a second. The North American standard is 60 cycles per second, known as 60 hertz (Hz).
Generation	The process of converting solar, thermal, mechanical, chemical or nuclear energy into electric energy.
Grid	A network of electric power lines and connections.

This Term …	Is defined as …
Harmonics	Sinusoidal currents and voltages with frequencies that are integral multiples of the fundamental power line frequency.
Hertz (Hz)	The unit of frequency for alternating current. Formerly called cycles per second. The standard frequency for power supply in North America is 60 Hz.
IEC	International Electrotechnical Commission. Refer to website: www.iec.ch
IEEE	Institute of Electrical and Electronics Engineers, Inc. Refer to website: www.ieee.org
Independent Power Producer (IPP)	A privately owned power generating facility, which may be connected to a utility system to supply electricity for domestic or export markets. Referred to as simply a "Power Producer" in this document.
Induction Generator	An induction machine that is driven above its synchronous or zero-slip speed by an external source of mechanical power in order to produce electric power. It does not have a separate excitation system and, as such, requires its output terminals to be energized with AC voltage and supplied with reactive power to develop the magnetic flux.
In-rush Current	The maximum current drawn from EDTI by the generator during the startup process.
Installed Capacity	The capacity measured at the output terminals of all the generating units in a station, without deducting station service requirements.
Interconnected System	A system consisting of two or more individual power systems connected together by tie lines.
Interconnection	The physical connection of distributed generation to EDTI’s distribution system so that parallel operation can occur.
Interconnection Point	See Point of Common Coupling.
Inverter	A machine, device, or system that changes direct current power to alternating current power.
Inverter Type Voltage-Following	Generating equipment that uses power electronic devices to produce a waveform, using the external voltage of the distribution system to control the electronic devices, in such a way that if the external voltage ceases, the electronic devices instantaneously stop producing the waveform.
Island (ing)	A condition where a portion of EDTI's distribution system is solely energized by one or more Power Producer generators, while electrically separated from the rest of the distribution system.
Isolated	A condition where a normally parallel generator becomes disconnected from EDTI's distribution system, but continues to supply only its own load. Only generators with stand alone capability are able to operate isolated.
Kilovar (kvar)	1000 vars. See Reactive Power.
Kilovolt (kV)	1000 volts.

This Term …	Is defined as …
Kilovolt Ampere (kVA)	1000 volt amperes. See Apparent Power.
Kilowatt (kW)	The commercial unit of electric power; 1000 watts. A kilowatt can best be visualized as the total amount of power needed to light ten 100 watt light bulbs.
Kilowatt hour (kWh)	The commercial unit of electric energy; 1000 watt hours. A kilowatt hour can best be visualized as the amount of electricity consumed by ten 100 watt light bulbs burning for an hour.
Load	The amount of electric power delivered or required at any specified location.
Load Factor	The ratio of the average load during a designated period to the peak or maximum load in that same period. Usually expressed in percent.
Load Forecast	The anticipated amount of electricity required by customers in the future.
Megavar (Mvar)	1000 kvars.
Megavolt Ampere (MVA)	1000 kVA.
Megawatt (MW)	A unit of bulk power; 1000 kilowatts.
Megawatt hour (MWh)	A unit of bulk energy; 1000 kilowatt hours.
NRTL	Nationally Recognized Testing Laboratory. A laboratory approved to perform the certification testing requirements for generating facilities.
NEMA	National Electrical Manufacturers Association. Refer to website: www.nema.org
Non-exporting	Designed to prevent any transfer of electrical energy from the generating facility to EDTI's distribution system.
Overfrequency	Refers to the abnormal operating state or system condition that results in a system frequency above the normal 60 Hz.
Parallel (Operation)	The operation of a generating unit, while connected to either the Alberta Interconnected Electric System or a smaller separate electric power grid, in parallel with other sources of electric power generation.
Peak Demand	The maximum power demand registered by a customer or a group of customers or a system in a stated period of time. The value may be the maximum instantaneous load or more, usually the average load over a designated interval of time, such as one hour, and is normally stated in kilowatts or megawatts.
Point of Common Coupling (PCC)	The point where EDTI's electrical facilities or conductors are connected to the Power Producer's facilities or conductors, and where any transfer of electric power between the Power Producer and EDTI takes place. Also referred to as the "Point of Interconnection" or "Interconnection Point".
Power	The rate of doing work. Electric power is measured in watts.
Power Factor	The ratio of active power to apparent power. It is the cosine of the phase angle difference between the current and voltage of a given phase.

This Term …	Is defined as …
Power Pool	The organization that operates the market for all electric energy bought or sold in Alberta. Refer to website: www.powerpool.ab.ca
Power Producer	A person or an organization interconnected to EDTI's distribution system for the purpose of producing electric power from an unregulated generating facility.
Power System	The interconnected facilities of an electrical utility. A power system includes the generation, transmission, distribution, transformation, and protective components necessary to provide service.
Reactive Power	Defined as the square root of the square of the apparent power, minus the square of the active power. Reactive power is developed when there are inductive, capacitive or nonlinear elements in the system. It is measured in vars.
Resonance	Resonance of a circuit or system refers to the enhancement of its response to a periodic excitation and usually results in very high currents and voltages.
RMS (Root-Mean-Square)	The equivalent heating value of a current or voltage waveshape. It is defined mathematically as the square root of the average of the square of the value of the function taken throughout one period. For a sinusoidal waveshape, the rms value is equal to the peak value divided by 1.414.
Secondary Injection Testing	A method in which low level signals obtained from current and voltage signal generators are injected into a power system protective device to test device response.
Self-Generation	Generation of electricity by a customer for their own use.
Simulated Utility	An assembly of variable frequency and variable voltage test equipment used to simulate a normal utility source.
Stabilized	Will be used to refer to EDTI's distribution system, returning to the normal range of voltage and frequency following a disturbance.
Stand Alone (Capability)	Distributed generation that can operate by controlling the frequency and voltage of their facility while in islanded or isolated mode.
Synchronous Generator	An alternating current machine in which the rotational speed of normal operation is constant, and when interconnected, is in synchronism with the frequency and in step with the voltage of the electric utility system.
System Controller (SC)	A provincially appointed authority responsible for dispatching load and generation on the Alberta Interconnected Electric System, in real time.
Target (Operation Indicator)	A supplementary device operated either mechanically or electrically, to indicate visibly that the relay or device has operated or completed its function.
Telemetering	Transmission of measurable quantities using telecommunications techniques.
Total Harmonic Distortion (THD)	Is defined as the ratio of the root-mean-square of the harmonic content to the root-mean-square value of the fundamental quantity, expressed as a percent of the fundamental.
Transformer	An electromagnetic device for changing the voltage of alternating electricity.
Transmission Facility	Any powerline or transformation equipment under the authority of the Transmission Facility Owner. Transmission facilities operate at voltages above 25 kV nominal, line to line.

This Term …	Is defined as …
Transmission Administrator (TA)	A provincially appointed authority providing access to the province wide transmission grid. The role of the TA is to provide system access service on the interconnected electric system in a manner that gives all eligible persons wishing to exchange electric energy through the Power Pool a reasonable opportunity to do so. Refer to the TA website: www.eal.ab.ca
Trip Time	The time between the start of the abnormal condition and the interconnection device ceasing to energize the distribution system.
Type Test	A test performed on a sample of a particular model of a device to verify specific aspects of its design, construction and performance.
UL	Underwriters Laboratories. Refer to website: www.ul.com
Underfrequency	Refers to the abnormal operating state or system condition that results in a system frequency below the normal 60 Hz.
Visible-break Disconnect	A disconnect switch or withdrawable circuit breaker which can simultaneously disconnect under full load the generator and all protective devices and control apparatus from the circuits supplied by the generator. The switch or breaker shall be provided with the means for adequate visible inspection of all contacts in the open position, and the blades or moving contacts shall be connected to the generator side.
Voltage	The electrical force or potential that causes a current to flow in a circuit (just as pressure causes water to flow in a pipe). Voltage is measured in volts (V) or kilovolts (kV). 1 kV = 1000 V.
Voltage Flicker	A condition of fluctuating voltage on a power system that can lead to noticeable fluctuations in the output of lighting systems.
Watt	The scientific unit of electric power. A typical light bulb is rated 25, 40, 60 or 100 watts. A horsepower is 746 watts.
Western Electricity Coordinating Council (WECC)	The Western Electricity Coordinating Council is one of the ten regional councils of the North American Electric Reliability Council that provides the coordination essential in operating and planning a reliable and adequate electric power system for the western part of the continental United States, Canada, and Mexico. Formerly named the WSCC. Refer to the WECC website: www.wscc.com

2. INTRODUCTION

This guideline establishes criteria and requirements for the interconnection of distributed resources within the distribution system of EPCOR Distribution & Transmission Inc. (EDTI). (EDTI). Specifically, this guideline defines the technical requirements for connecting generation that is not exclusively owned by EDTI, but is connected to EDTI facilities, with an operating voltage of 25,000 volts (25 kV) or lower. Requirements relevant to the safety, performance, operation, testing and maintenance of the interconnection are provided.

The requirements established in this document cover a broad spectrum of interests. The addition of distributed resources to the distribution system may change the system and its response. Attaining a technically sound, strong and safe interconnection among distributed resources and the distribution system mandates diligence on the part of everyone involved in the interconnection. The requirements in this guideline need to be cooperatively understood and met among everyone involved in the interconnection including designers, manufacturers, users, owners and operators of both distributed resources and distribution systems.

This guideline has been developed with reference to international standards such as the Institute of Electrical and Electronic Engineers (IEEE) standard P1547, *DRAFT Standard for Interconnecting Distributed Resources with Electric Power Systems.*

This document does not constitute a design handbook. Power Producers who are considering the development of a generation facility intended for connection to EDTI's distribution system should engage the services of a professional engineer or a registered consulting firm qualified to provide design and consulting services for electrical interconnection facilities.

3. LIMITATIONS

The criteria and requirements in this document are applicable to all distributed resource technologies and to the primary and secondary voltages of the electric power distribution systems. Installation of distributed resources on radial primary and secondary distribution systems is the main emphasis of this guideline (restrictions with regards to EDTI's downtown network distribution system are described in section 4.3.8). The requirements in this document shall be met at the Point of Common Coupling (PCC), although the location of the protective devices may not necessarily be at that point.

This interconnection guideline is a minimum requirement for the interconnection of distributed resources. Additional requirements may have to be met by both the Power Producer and EDTI to ensure that the final interconnection design meets all local and national standards and codes, and is safe for the application intended.

This guideline does not address any liability provisions agreed to elsewhere by both parties in a commercial agreement or tariff terms and conditions.

4. GENERAL INTERCONNECTION AND PROTECTION REQUIREMENTS

The Power Producer's generation and interconnection installation must meet all applicable national, provincial and local construction and safety codes.

Any Power Producer may operate 60 Hertz, three-phase or single-phase generating equipment, in parallel with EDTI's System and in accordance with EDTI's *Interconnection Operating and Maintenance Agreement*, provided the equipment and Power Producer meets or exceeds the requirements of this guideline.

The following three sections, 4.1, 4.2, and 4.3, respectively define the:

- Distribution system's technical requirements. The Power Producer's equipment must be able to operate within the ranges specified in this section.
- Technical requirements to be met by the Power Producer.
- Technical requirements to be met by the facilities interconnecting the producing facility with the distribution system.

These requirements promote safe operation and minimize the impact on electrical equipment within the EDTI System including other customers. These requirements do not address the protection for the Power Producer's generation equipment. It is the responsibility of the Power Producer to provide such protection. The Power Producer is responsible for protecting the Power Producer's generating equipment in such a manner that utility system outages, short circuits or other disturbances, including excessive zero sequence currents and ferroresonant overvoltages, do not damage the Power Producer's generating equipment. As required in this guideline, the Power Producer's protective equipment must also prevent excessive or unnecessary tripping that would affect EDTI's reliability and power quality to other customers.

The Power Producer is required to install, operate and maintain, in good order and repair and in conformity with good electrical practice, the facilities required by this guideline for safe parallel operation with EDTI's distribution system.

Refer to Tables 1, 2 and 3 and Appendix 1, 2 and 3 for summary tables and single line diagrams showing typical interconnection protection requirements.

4.1 DISTRIBUTION SYSTEM

4.1.1 General Characteristics

Each distribution circuit on EDTI's distribution system is normally radial supplied from a single substation. EDTI's distribution circuits operate at 4.16 kV, 13.8 kV or 25 kV nominal line-to-line voltages.

Some areas of the downtown core of Edmonton are operated as a network system, with multiple paths for power to flow from an EPCOR substation to the customer. Reverse power flow from the customer back through the secondary network is not allowed. Refer to the requirement for reverse power protection (See 4.3.8).

Three-phase primary voltage service is available on 13.8 kV and 25 kV circuits.

4.1.2 System Frequency

The Alberta Interconnected Electric System (AIES) operates nominally at 60 Hertz (Hz) alternating current (AC). Frequency deviations are typically 59.7 Hz to 60.2 Hz for small contingencies that cause modest disturbances, when the AIES remains intact and connected to the Western System.

For large contingencies, variations of 58 Hz to 61 Hz or greater can occur. These variations can be experienced when a portion of the AIES becomes islanded.

4.1.3 Voltage Regulation

CSA Standard CAN3-C235-83 *Preferred Voltage Levels for AC Systems 0 to 50 000 V,* provides general guidance for appropriate performance.

4.1.4 Power Quality

All interconnected equipment must comply with EDTI's standards for power quality. The following industry standards provide guidance for appropriate performance.

- Voltage Flicker - IEEE Std. 519-1992 *IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power System*

- Harmonics - IEEE Std. 519-1992 *IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power System*

According to the IEEE 519 standard, the recommended practice for utilities is to limit the maximum individual frequency voltage harmonics to 3% of the fundamental frequency and the voltage total harmonic distortion (THD) to 5% on the utility side of the Point of Common Coupling (PCC). These harmonic voltage limits can be used as system design values for the "worst case" under normal operation.

4.1.5 Voltage Unbalance

Distribution facilities are typically three-phase systems incorporating single-phase distribution taps. Under normal operating conditions, the voltage unbalance on EDTI's distribution system may reach 3%, due to unbalanced loading and single-phase regulation. Voltage unbalance will be calculated using the following formula derived from NEMA MG 1-1998 14.36:

$$\text{Voltage Unbalance (\%)} = \frac{100 \times \text{(maximum voltage deviation from average voltage)}}{\text{(average voltage)}}$$

4.1.6 Fault Levels

Fault levels, including maximum allowable fault levels, vary significantly throughout a distribution system. These must be considered in the design of the interconnection. Fault levels and X/R ratios must be evaluated for the equipment selected.

The Power Producer's facility must not increase fault levels on EPCOR's distribution or transmission system above each system's design levels for maximum faults (See 4.3.11).

4.1.7 System Grounding

Distribution facilities are typically operated as effectively (solidly) grounded and wye-connected at the source substation bus.

Distribution facility grounding must conform to the Alberta Electrical and Communication Utility Code (formerly the Alberta Electrical and Communication Utility System Regulation 44/1976 or future amendments).

4.1.8 Fault and Line Clearing

To maintain the reliability of the distribution system, EDTI typically uses automatic reclosing. The Power Producer needs to take into consideration line reclosing when designing generator protection schemes. This is to ensure that the generator is disconnected from EDTI's distribution system prior to the automatic reclose of breakers. The Power Producer may reconnect when EDTI's system voltage and frequency return to the normal range and is stabilized.

4.2 Generating Facility

4.2.1 Mitigation of Adverse Effects

Adding a generating facility to a distribution system can adversely affect the electric service to existing or future electric customers. The Power Producer shall work with EDTI to mitigate any unfavorable effects.

If the generating facility is affecting customers adversely, EDTI may disconnect it until the concern has been mitigated. The Power Producer will be responsible for any costs incurred as a result of these actions.

4.2.2 Synchronism

Any generating facility that can create a voltage, while separate from the electric system, must have synchronization facilities to allow its connection to the electric system.

Synchronization facilities are not required for:

- inverter type voltage-following equipment that cannot generate a voltage while separate from the electric system.
- induction generators that act as motors during startup, drawing power from the electric system before they themselves generate power.

EDTI cannot synchronize to the generating facility. The generating facility has the responsibility to synchronize and maintain synchronization with the EDTI System. A proposed synchronizing scheme must be submitted and outlined in the *Interconnection Operating and Maintenance Agreement.*

Synchronization equipment must prevent connection to EDTI's System when the Power Producer's synchronous generator and/or power system is operating outside the following limits:

Aggregate Ratings Of Generation (kVA)	Frequency Difference (Hz)	Voltage Difference (%)	Phase Angle Difference (degrees)
0 - 500	0.3	10	20
501 – 1500	0.2	5	15
>1500	0.1	3	10

Distribution and transmission facilities typically allow for automatic reclosing of electrical circuits after a variable time delay. The Power Producer is responsible for protecting their facility from the effects of such reclosing.

Generators with a total capacity of less than 100 kW can automatically restart following automatic reclosing of distribution facility electrical equipment if agreed to with EDTI. Generators that automatically restart must have a time delay on restart with an adjustable range of 1 - 60 minutes. EDTI will coordinate the settings of generator restart time delays so that generators on any feeder can restart in a staggered order.

4.2.3 Voltage Regulation and Power Factor

The Power Producer is responsible for ensuring that the voltage levels at the Point of Common Coupling (PCC) are maintained within the guidelines prescribed by EDTI. Voltage levels must be at least equal to the voltage levels at all feeder load conditions, prior to the interconnection.

Synchronous generators connected to the distribution system must be equipped with excitation controllers capable of controlling voltage. The generator bus voltage set point shall be stable at, as well as adjustable to, any value between 95% and 105% so that EDTI can maintain CSA voltage limits on its system.

Induction generators do not have voltage or reactive power control and consume reactive power (VAR). In this case, the generator must provide reactive compensation to correct the power factor to ± 0.9 at the PCC, unless other terms are negotiated with EDTI.

Inverter type generating equipment can control the power factor over a wide range, typically ± 0.75. An inverter type generator connected to the distribution facility must be capable of adjusting the power factor in the range of ± 0.9. The Power Producer may operate outside that range only by prior agreement with EDTI.

EDTI will define voltage and reactive power control requirements on a project by project basis. The Power Producer and EDTI will identify the exact transformer ratio to allow best voltage regulation on the system and determine whether an onload tap changer is needed.

In order to coordinate with its existing voltage control devices, EDTI may require that the generator operate in a power factor control mode. This means operating within a constant power factor set point range. The voltage/power factor regulator must be capable of controlling the power factor of the generator between +0.9 and -0.9. EDTI shall determine the actual set point between these limits.

In power factor control mode, the voltage regulator must have a voltage override that causes it to reduce excitation if the voltage at the PCC exceeds an upper limit to be specified by EDTI. The normal upper limit is 105% of nominal; however, the voltage regulator shall have the provision to adjust this upper limit between 100% and 110% of nominal. The voltage regulator must also have provision for a time delay between sensing an excursion of the upper voltage and initiating control action. The power factor control equipment must have the capability to allow for the adjustment of this time delay from between 0 and 180 seconds. EDTI will specify the required time delay.

4.2.4 Frequency Control

An interconnected generating facility must remain synchronously connected for frequency excursions as identified in this guideline and in the table below.

Islanded operations are not allowed for generators connected to EDTI's distribution system (See 4.3.16). Generators with stand alone capability, that serve isolated systems, must be capable of controlling the frequency of the system to between 59.7 Hz to 60.2 Hz for normal operation.

Underfrequency and overfrequency relaying that automatically disconnects generators from the AIES must not operate for frequencies in the range of 59.5 to 60.5 Hz.

The frequency of the electric system is controlled by all synchronous generator governor systems that connect to the electric system. Such governor systems respond automatically to changes in system frequency to prevent further deviation. Synchronous generators (and other generators with stand alone capability) having a rated capacity of 10 MW or more must have a droop governor. The droop setting of the governor shall be 5%, and the governor system must be operated at all times so that it is free to respond to system frequency changes. If a 5% setting is not possible, the Power Producer must obtain acceptance from the Transmission Administrator for a different droop setting.

In accordance with the Transmission Administrator and Western Electricity Coordinating Council's off-frequency requirements, generators connected to the grid that protect for off-nominal frequency operation should have relaying protection that accommodates, as a minimum, underfrequency and overfrequency operation for the following specified time frames:

Underfrequency Limit	Overfrequency Limit	Minimum Time
60.0 - 59.5 Hz	*60.0 - 60.5 Hz*	*N/A (continuous operating range)*
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	Instantaneous trip

Generators that do not meet the above requirements and trip off the grid in a shorter time than indicated shall automatically trip load simultaneously to match the anticipated generation loss, at comparable frequency levels.

4.2.5 Voltage Unbalance

The phase-to-phase voltage unbalance must not exceed 1% for any three-phase generating facility, as measured both with no load and with balanced three-phase loading. Voltage unbalance will be calculated using the same formula as in section 4.1.5.

Single-phase generators must not adversely unbalance the three-phase system. When they are connected in multiple units, an equal amount of generation capacity must be applied to each phase of a three-phase circuit. The group of generators must also maintain balance when one unit trips or begins generating before or after the others. A single-phase generator may be connected alone, only if it does not cause voltage unbalance on EDTI's distribution system in excess of 2%.

4.2.6 Grounding

A ground grid of sufficient size to handle the maximum available ground fault current shall be designed and installed in order to limit step and touch potentials to safe levels as set forth in ANSI/IEEE Std. 80 *IEEE Guide for Safety in AC Substation Grounding*. All electrical equipment must be grounded in accordance with Alberta Electrical and Communication Utility Code (AECUC) and Canadian Electrical Code's electrical and safety codes. The ground grid must be approved by EDTI.

4.2.7 Resonance and Self-Excitation of Induction Generators

Resonance should be considered in the design of the Power Producer's facility, as certain resonance can cause damage to existing electrical equipment, including the electrical equipment of the Power Producer. Engineering analysis by the Power Producer should be a part of the design process to evaluate the existence of and to eliminate the harmful effects of:

a) ferroresonance in the transformer (Refer to Appendix 6, Note 1),

b) sub-synchronous resonance due to the presence of series capacitor banks (Refer to Appendix 6, Note 2), and

c) resonance with other customers' equipment due to the addition of capacitor banks to the distribution system (Refer to Appendix 6, Note 3).

For Power Producers connecting induction generators, the adverse effects of self-excitation of the induction generator during island conditions should be assessed and mitigated. The intent is to detect and eliminate any self-excited condition (Refer to Appendix 6, Note 4).

The engineering analysis of resonance and the assessment of the effect of self-excitation of induction generators should be submitted to EDTI for approval or further evaluation.

4.2.8 Single-Phase Generating Facilities

For single-phase generating facilities connected to a shared single-phase secondary, the maximum aggregate capacity shall be 10 kVA. For dedicated distribution transformer services, the limit of a single-phase generating facility shall be the transformer nameplate rating.

4.3 INTERCONNECTION

4.3.1 Safety

Safety of personnel, the public and equipment is of primary concern in the design of the interconnection.

4.3.2 Point of Common Coupling

The Point of Common Coupling (PCC) is the point where EDTI's electrical facilities or conductors are connected to the Power Producer's facilities or conductors, and where any transfer of electric power between the Power Producer and EDTI takes place. The PCC will be identified in the design and on the single line diagram. EDTI will coordinate design, construction, maintenance and operation of the facilities on the distribution side of the point of common coupling. The Power Producer is responsible for the design, construction, maintenance and operation of the facilities on the generation side of the point of common coupling.

In specific cases, either EDTI or the Power Producer may own equipment located on the other's side of the PCC. For example, EDTI may own and operate communications, supervisory, or metering equipment, which is located on the Power Producer's side of the PCC.

The Power Producer must provide a site with the necessary space for EDTI to install current transformers, potential transformers, switching equipment, meters, and any other controls or communications equipment required to interconnect with the generating facility. The site is to be approved by EDTI and a 120-volt AC power service is to be available for the use of portable tools.

All voltage, frequency and harmonic parameters, as specified in the following sections, shall be met at the PCC unless otherwise stated.

4.3.3 Point of Disconnection

To provide a means of electrically isolating the EDTI System from the generator, a manual and visible disconnect switch must be installed at the Point of Common Coupling (PCC). Where the generating facilities are located far from the PCC, the Power Producer may be allowed to install a local point of isolation next to the generator. EDTI and the Power Producer will mutually agree on the exact location of the switch.

If the switch is to be located on EDTI's side of the PCC, it will be installed by EDTI at the Power Producer's expense. If the switch is to be located on the Power Producer's side of the PCC, it must be supplied and installed by the Power Producer.

When the interconnection involves three-phase generators, the disconnect switch must be gang operated to simultaneously isolate all three-phases.

All disconnect switches must:

- be within 5 meters (horizontal) of the Point of Common Coupling, or an EDTI approved location.
- be capable of being opened at rated load.
- have contact operation that is verifiable by directly visible means.
- be readily accessible to EDTI operating personnel on a 24 hour basis.
- have provision for being locked in the "open" position.
- disconnect all ungrounded conductors of the circuit, simultaneously.
- be externally operable without exposing the operator to contact with live parts.
- be capable of being closed onto a fault with complete safety for the operator.
- be capable of being energized from both sides.
- plainly, indicate whether it is in the "open" or "closed" position.
- provide safe isolation for EDTI personnel from the generators and all other possible customer sources of power.
- be labeled with an EDTI switch number.
- meet applicable CEC Part I and Part II standards.
- be installed to meet all applicable codes.
- be annually inspected and maintained.

The disconnect switch on the generation side of the interconnection transformer will be owned and maintained by the Power Producer. Refer to Appendixes 1, 2 and 3 for a sample configuration.

On a site that interconnects multiple generators, one disconnect switch must be capable of isolating all the generators simultaneously.

A withdrawable circuit breaker is an acceptable disconnect device.

The Power Producer shall follow EDTI's switching, clearance, and tagging procedures. EDTI shall instruct the Power Producer on these procedures.

There may be other means of meeting the requirements of this section. EDTI must approve any other means.

4.3.4 Phasing

Since phasing is not standardized across distribution facilities, the phase sequence and the direction of rotation must be coordinated between the Power Producer and EDTI's System.

4.3.5 Voltage Flicker

The Power Producer must not cause excessive voltage flicker on EDTI's facilities. Any voltage flicker at the Point of Common Coupling that is caused by the generating facility should not exceed the limits defined by the "Maximum Borderline of Irritation Curve" identified in Fig. 10.3 of IEEE Std. 519-1992 *IEEE Recommended Practices and Requirements for Harmonic Control in Electric Power Systems*. This is necessary to minimize any adverse voltage effects that could be experienced by other customers on EDTI's distribution system.

Induction generators may be connected and brought up to synchronous speed (as an induction motor) if these flicker limits are not exceeded. The Power Producer must submit the expected number of starts per specific time period and the maximum starting current draw data to EDTI in order to verify that the voltage dip due to starting is within the IEEE limits. At no time should the voltage drop exceed 5% as measured on EDTI's side of the PCC. Otherwise, the Power Producer will be required to install corrective step-switched capacitors or apply other techniques to bring voltage fluctuations to acceptable levels. These corrective measures could, in turn, cause ferroresonance and therefore EDTI must review any measures undertaken on the Power Producer's side of the PCC.

4.3.6 Harmonics

The Power Producer's operation of their generating facility must not cause an unacceptable level of harmonics. Maximum harmonic current distortion limits for power generation equipment, measured at the Point of Common Coupling, are as specified in Table 10.3 of IEEE Std. 519-1992 *IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power System*.

The objective of the current distortion limits in IEEE 519 is to limit the harmonic injection from individual customers. This is to ensure that they do not cause unacceptable voltage distortion levels to normal system characteristics. Ideally, the voltage distortion would then be limited to 3% of the fundamental frequency for individual harmonic frequencies and 5% voltage total harmonic distortion (THD) on EDTI's side of the PCC.

Generating facilities must not inject DC current greater than 0.5% of the full rated output current into EDTI's distribution system under normal or abnormal operating conditions.

4.3.7 Inadvertent Energization of EDTI's Facilities

When EDTI's facilities are de-energized for any reason, the Power Producer's generator must not energize EDTI's facilities.

4.3.8 Network System Interconnection

Distributed generation facilities that export power onto EDTI's distribution system, will not be allowed to connect to the downtown network system. This restriction is required because EDTI uses network protectors for reverse power protection throughout the downtown's networked underground distribution system. Network protector manufacturers and IEEE C37.108 specifically recommend against utilization of network protectors in a Distributed Resource application.

For non-exporting distributed generation facilities, EDTI may allow parallel operation on the network system if:

- the Power Producer installs reverse power protection for the facility (See 4.3.18).
- reverse power protection settings prevent any cycling operation of network protectors due to the output of the distributed generation.
- the network equipment loading and fault interrupting capacities are not exceeded by the addition of the distributed generation.

4.3.9 Dedicated Transformer

EDTI reserves the right to require a Power Producing facility to connect to the distribution system through a dedicated transformer. A dedicated transformer is a transformer with a secondary winding that serves only one customer. The transformer may be necessary to:

- ensure conformance with EDTI safe work practices.
- enhance service restoration operations.
- prevent detrimental effects to other EDTI customers.

The dedicated transformer, that is part of the normal electrical service connection of a Power Producer's facility, may meet this requirement if there are no other customers supplied from it. A dedicated transformer may not be required, if the installation is designed and coordinated with EDTI to protect the EDTI System and its customers adequately from potential problems caused by the operation of the generator.

4.3.10 Interconnection Grounding

Grounding configurations shall be designed to provide:

- solidly grounded distribution facilities.
- suitable fault detection to isolate all sources of fault contribution, including the generator, from a faulted line or distribution element.
- a circuit to block the transmission of harmonic currents and voltages.
- protection of the low voltage side from high fault current damage.

For three-phase secondary voltage service on 4.16 kV and 13.8 kV circuits, the EDTI supplied distribution transformer will normally be a delta configuration on the high voltage side and a grounded-wye configuration on the low voltage side. For three-phase secondary voltage service on 25 kV circuits, the EDTI supplied distribution transformer will normally be a grounded-wye configuration on both the low and high voltage side.

The preferred configuration, for a Power Producer owned interconnection transformer, is delta connection on the generator side of the transformer and a grounded-wye configuration on EDTI's side of the transformer. If this configuration is not possible, the configuration chosen must still address the above concerns. The winding configuration for distributed generator interconnection transformers must be reviewed and approved by EDTI.

4.3.11 Interrupting Device Ratings and Fault Levels

The design of the generating facility must consider the fault contributions from both the distribution facility and the generating facility to ensure that all circuit fault interrupters are adequately sized. EDTI will inform the Power Producer of the present and anticipated future fault contributions from the interconnected electric system, including fault level design limits.

For generators that have time-variant fault contribution characteristics, the characteristic producing the highest fundamental frequency fault current shall be used for maximum fault current calculations. For synchronous and induction generators, the subtransient reactance shall be used.

Inverter type systems are different from rotating machines in that fault currents are typically only marginally greater than full load current.

The ground fault contribution (3Io) of the distributed generation (DG), including the effect of any transformers between the DG and the primary feeder, shall not be greater than 100% of the fault current contribution of the DG to a three-phase fault at the same primary feeder location. This ground fault current limitation shall not apply to any DG interconnected through an existing EDTI distribution transformer where the neutral grounding of the high voltage winding is unchanged.

EDTI will perform fault level calculations based upon the Power Producer's supplied data for proposed generator and transformer impedances. EDTI will advise the Power Producer if the proposed facility exceeds EDTI's maximum design fault levels. If the calculated fault contribution from the proposed facility increases the fault levels on either EPCOR's distribution or transmission system above the maximum design levels, then the Power Producer will be required to redesign their facility to reduce fault level contributions. This may involve one or more of the following mitigation techniques:

- select a generator with a larger subtransient impedance.
- select a higher impedance generator transformer.
- install current-limiting reactors or other fault current limiting devices.

If the fault level contributions from the facility cannot be reduced to an acceptable level, then EDTI will not allow the interconnection of the Power Producer's facility.

4.3.12 Phase and Ground Fault Protection

The Power Producer must install protective devices to detect and promptly isolate the generating facility for faults occurring in the generating facility or on the distribution system. 'Virtual devices' such as computer or programmable logic controller systems are acceptable provided they meet standard utility practice for system protection and they have been type tested and approved by an independent testing laboratory.

The detection of ground faults on the distribution system may not be required if the generator is an inverter type voltage-following system of less than 50 kW aggregate. In this case, EDTI will inform the Power Producer if protection devices are required.

The generating facility's protective devices must fully coordinate with protective relays on the electric system unless otherwise agreed. The Power Producer must calculate the protective device settings and submit the relay characteristics and settings to EDTI for review and approval.

The generation facility must be able to detect the following situations and isolate itself from the distribution facility:

- a short circuit between any phase(s) and ground.
- a short circuit between phase(s).
- loss of any phase(s).

4.3.13 Overvoltage and Undervoltage Protection

The Power Producer will operate its generating equipment in such manner that the voltage levels on the EDTI distribution system are in the same range as if the generating equipment were not connected to the distribution system.

The Power Producer must install necessary relays to trip the circuit breaker when the voltage, measured phase-to-ground, is outside predetermined limits. Undervoltage relays should be adjustable and should have a time delay setting to prevent unnecessary tripping of the generator on external faults. Overvoltage relays should be adjustable and may be instantaneous.

The Power Producer's interconnection device shall cause the generator to cease to energize EDTI's distribution system within the 'trip times' as indicated below. Trip time is the time between the start of the abnormal condition and the interconnection device ceasing to energize EDTI's distribution system.

Response to Abnormal Voltages

RMS Voltage: V≤60 (V≤50%)	Trip time: Instantaneous
RMS Voltage: 60<V<108 (50%<V<90%)	Trip time: 120 cycles
RMS Voltage: 108≤V≤127 (90%≤V≤106%)	Normal Operation
RMS Voltage: 127<V<144 (106%<V<120%)	Trip time: 30 cycles
RMS Voltage: V≥144 (V≥120%)	Trip time: Instantaneous

The Power Producer may reconnect when EDTI's system voltage and frequency return to normal range and is stabilized for a time period greater than 5 minutes.

4.3.14 Overfrequency and Underfrequency Protection

The Power Producer must install frequency selective relays to separate the generator(s) from the electric system in cases of extreme variations in frequency.

Underfrequency and overfrequency relaying that automatically disconnects generators from the distribution system must be time delayed in accordance with the Transmission Administrator's requirements as noted in section 4.2.4. The Power Producer may reconnect when EDTI's distribution system voltage and frequency return to a normal range and is stabilized.

4.3.15 Unbalanced Phase Protection

The Power Producer should be aware that single-phase protection devices exist on EDTI's distribution system. Unbalanced current conditions caused by open conductors on the distribution system can subject the generator to a high level of negative sequence current. The Power Producer is responsible for protecting their generating equipment from the effects of excessive negative sequence currents in the event of single phasing. Negative sequence current relaying is recommended.

4.3.16 Anti-Islanding

In most cases, the generating facility will routinely operate as a part of the interconnected system. A problem on the AIES could lead to the generator becoming islanded and inadvertently the sole producer of power to one or more of EDTI's customers. This could result in damages to those customers and liability to the Power Producer because of irregularities in power quality. The Power Producer's generator must be equipped with protective hardware and software designed to prevent the generator from being connected to a de-energized EDTI circuit.

The prevention of an unintended island can be accomplished by one of the following options:

(1) incorporating certified anti-islanding control functions, approved by EDTI, into the generator protection scheme, or

(2) verifying that local loads sufficiently exceed the load carrying capability of the distributed generation facility (reverse power relay will provide sufficient protection in this case), or

(3) incorporating a 'transfer trip' or an equivalent function into the generator protection scheme.

At the discretion of EDTI, the Power Producer may be allowed to install underfrequency tripping at 59.4 Hz and overfrequency tripping at 60.6 Hz at a time delay of 0.5 seconds for the purposes of anti-islanding. In these cases, EDTI will add an equivalent amount of load to EDTI's underfrequency load shedding blocks to match the generation loss.

For situations where there could be a reasonable match between the Power Producer's exporting generation and islanded load, conventional methods may not be effective in detecting islanded operation. Under these circumstances, EDTI will require the addition of transfer trip communication facilities to remotely trip either the generator or the main breaker located at the PCC upon opening of EDTI's substation feeder breaker or automatic circuit recloser (See 4.3.17). As an alternative, EDTI may approve the use of an anti-islanding protective relay (loss-of-mains relay) that performs the equivalent function of a transfer trip scheme.

<u>Damages that are caused because of a failure to safely separate during an islanding event will be the responsibility of the Power Producer.</u>

4.3.17 Requirements for Transfer Trip (Exporting Generators Only)

All synchronous generators that are rated 500 kW or larger with the ability to export power onto EDTI's distribution system, must be equipped with transfer trip protection or an EDTI approved anti-islanding relay that performs the equivalent function of a transfer trip. This is to ensure that these generators do not island in the event of a substation breaker or intermediate automatic circuit recloser opening. General requirements are:

- Generator lockout or lockout of main breaker (for distributed generation facilities that desire to operate isolated) at PCC location within 0.6 seconds of the EDTI substation feeder breaker or the automatic circuit recloser opening.

- Fail safe lockout within 6 seconds of communication loss.

- Power Producer has the responsibility for detecting and tripping in the event of communication loss.

Synchronous generators smaller than 500 kW may also require this protection depending upon the characteristics of the particular distribution circuit to which they are connected. EDTI will inform the Power Producer of the requirements in these cases.

Unless the Power Producer can demonstrate that there is no potential for self-excitation, transfer tripping requirements also apply to induction generators.

4.3.18 Reverse Power Relay Protection

Reverse power protection must be installed on non-exporting or export limited generating facilities that are connected in parallel to the EDTI System.

Until the Power Producer has received all the necessary licenses and permits, all generating facilities require reverse power protection while connected in parallel to the EDTI System. An option for the Power Producer is to install an interlocking device that will prevent any electrical connection between the generator and the EDTI distribution system.

The setting for the reverse power protection (IEEE device 32) shall be the export or non-export limit as agreed to by EDTI, with a maximum two second time delay.

4.3.19 Telemetry and Targeting

Where a generator could adversely affect the power system, the Power Producer must have systems in place to inform EDTI what protective operations occurred or failed to occur. An example of an adverse effect would be the Power Producer's generator providing inflow into a fault.

The Compliance Monitoring and Operating Practices Subcommittee of the WECC requires distribution and transmission facilities owners and the System Controller to provide telemetry of MW, Mvar and breaker status of all significant generation. 'Significant' is presently defined as a capacity of greater than or equal to 5 MW, although in some sensitive areas of the distribution system, EDTI may require telemetry or transfer trip for smaller generators.

4.3.20 Protection from Electromagnetic Interference

The influence of electromagnetic interference (EMI) must not change the state or operation of the interconnection between EDTI and the Power Producer's systems.

4.3.21 Surge Withstand Performance

The interconnection system must have the capability to withstand voltage and current surges in accordance with the environments described in IEEE/ANSI C62.41 or C37.90.1.

4.3.22 Special Interconnection Protection

In some cases, it will be necessary to provide for special generator specific protection and controls, such as for out-of-step or loss of synchronism between the Power Producer and EDTI.

Unbalance conditions can occur in the distribution system, especially under system fault conditions, and the design of the interconnection facilities should consider this.

For wye-delta interconnection transformers, the unbalance fault current could damage the generator interconnection transformer. The damage can occur because of the circulating current that occurs in the delta winding of the interconnection transformer in its attempt to balance the fault current. Therefore, the design may require protection for the transformer to address this potential problem.

In cases where the Power Producer desires to automatically separate from EDTI's System and commence isolated operation, additional devices may have to be installed to effect separation.

4.4 Typical Interconnection Protective Requirements

Typical interconnection requirements for safely operating the Power Producer's generating equipment in parallel with EDTI's System are specified below. Specific interconnection locations and conditions may require more restrictive protective settings or hardware, especially when exporting power to the EDTI System. EDTI shall notify the Power Producer of special circumstances as soon as possible. An example of a restrictive area for distributed generation interconnection is EDTI's downtown network system. The Power Producer will need to work closely with EDTI to determine whether interconnection and operation within a specific network system is possible.

Protective relays shall be equipped with visual indicators (also referred to as targets) for various phase, ground, time, and starting and tripping indication. Dry contacts on the relay shall be supplied in the event EDTI requires monitoring of relay operation. Alarms generated by the generator facility are to be monitored by the Power Producer and appropriate action taken.

Only utility grade protection devices are approved for interconnection protection. Non-utility grade protection devices will be subject to review by EDTI.

Protective relays, electric conversion devices, or other devices can comply with this guideline by demonstrating that they can accomplish the required protective function as specified in Table 1, Table 2 and Table 3.

4.4.1 Single-Phase Generators

Refer to Table 1 for the protective functions required to meet this guideline. Inverter type generators must meet the criteria in: IEEE 929 - *Recommended Practice for Utility Interface of Photovoltaic (PV) Systems* and be certified to UL 1741 and CSA C22.2 No.107.1.

4.4.2 Three-Phase Synchronous Generators

Refer to Table 2 for the protective functions required to meet this guideline.

The Power Producer's generator circuit breakers must be three-phase devices with electronic or electromechanical control.

The Power Producer is responsible for:

- properly synchronizing its generator with the EDTI System.
- ensuring that the interconnection protection device settings coordinate with EDTI's protective device settings.

4.4.3 Three-Phase Induction Generators and Three-Phase Inverter Systems

Refer to Table 2 for the protective functions by generator size required to meet this guideline.

Inverter type generators must meet the applicable criteria in: IEEE 929 and be certified to UL 1741 and CSA C22.2 No.107.1.

Line-commutated inverters do not require synchronizing equipment. Self-commutated inverters, whether of the utility interactive type or stand alone type, require synchronizing equipment to be used in parallel with EDTI's System. Direct current generation must not be connected directly in parallel with EDTI's System.

4.4.4 Generators Paralleling for 30 cycles or Less (Closed Transition Switching)

Refer to Table 3 for the protective functions required by this guideline for generators 10 MW or less that parallel with the EDTI distribution system for 30 cycles or less.

Power Producers, whose generators meet these criteria, can submit an application and sign an *Interconnection Operating and Maintenance Agreement*, once they have met the other requirements of this guideline.

4.4.5 Mitigation of Protection System Failure

Relays with self-diagnostic check features provide information on the integrity of the protection system and should be used whenever possible. The design of protection should be done by a qualified professional engineer, or a competent technical person, working with EDTI engineers to ensure that this self-checking feature is integrated into the overall protection system for the safe and reliable operation of the power system.

Depending upon the system and its design, where relays with this self-diagnostic feature do not trip the appropriate breaker(s), sufficient redundant or backup protection should be provided for the power system. The malfunctioning relay should also send a signal to notify operating personnel to initiate an investigation of the malfunction.

Older electro-mechanical relays do not generally come with self-diagnostic features. In these instances, design of protection and control systems should be of a fail safe nature to maintain the integrity of the protection system under malfunction conditions.

The generating facility requires a reliable power supply comprised of a battery and battery charger for the protection to function. Capacitor trip units are not to be used and the preferred voltage level for the DC system is either 48VDC or 125VDC nominal. An annunciator system must be provided from the DC system to monitor both remotely and locally any change in voltage levels.

4.5 Interconnection Protection Approval

The Power Producer must provide complete documentation on the proposed interconnection protection for review against the requirements of this guideline and for potential impacts on EDTI's System.

The documentation should include:

- completed application form,
- overall description on how the protection will function,
- detailed single line diagram,
- protection components details (manufacturer, model),
- protection component settings (trigger levels and time values), and
- disconnect switch details (such as manufacturer, model and associated certification)

The Power Producer shall revise and resubmit the protection information for any proposed modifications.

5. CONSTRUCTION

5.1 General

The construction and installation of the Power Producer's generating facility must meet all applicable regulations. The Power Producer is responsible for obtaining all permits and complying with all safety and environmental regulations and codes. Copies of all permits, compliance reports and inspection documents must be provided to EDTI prior to energizing the Point of Common Coupling.

All single line diagrams provided to EDTI must be drawn in accordance with IEEE standards and conventions, and must be stamped by a professional engineer assuming responsibility for the design.

6. METERING

6.1 General

Metering must comply with Measurement Canada requirements, the latest revision of the Transmission Administrator's Measurement System Standard where applicable and be approved by EDTI.

The metering equipment must be:

- suitable for use in the environmental conditions reasonably expected to occur at the installation site, over the course of a typical year.

- appropriate for the power system characteristics reasonably expected to exist at the installation site under all power system conditions and events.

The primary side of the interconnection transformer, which is the side connected to EDTI's system, is the metering billing point for the Power Producer's generation export conditions. The low side of the interconnection transformer, which is the side connected to the Power Producer's facilities, is the metering billing point for the Power Producer's import conditions. On all installations where the metering equipment is installed on the low side of the interconnecting transformer, transformer loss compensation shall be installed in the meter for generation export conditions.

6.2 Meter Requirements

The meter must:

- be approved by Measurement Canada for revenue metering.
- be verified and sealed in accordance with the *Electricity and Gas Inspections Act*.
- be an interval meter except for sites with the exemptions as outlined in the *Settlement System Code of Alberta*.
- include an interval time-stamping clock (if the meter provides the interval data time-stamping function) capable of maintaining the interval boundaries within 60 seconds of the hour and every quarter hour thereafter according to Mountain Standard Time or Mountain Daylight Time whichever is then in effect in the province of Alberta.
- measure all quantities required to determine active energy and reactive energy being transferred in the required directions at the metering point.
- provide a separate register to maintain the continuously cumulative readings of the active energy and reactive energy being transferred in the required directions at the metering point.

- retain readings and, if applicable, all clock functions for at least fourteen (14) days in the absence of line power.
- have an accuracy class rating for active energy measurement that equals or exceeds the values specified in Appendix 4.
- have an accuracy class rating for reactive energy measurement that equals or exceeds the values specified in Appendix 4.
- be labeled "LOSS COMPENSATED" on those meters, which are internally compensated for line or transformer losses.

6.3 Measurement Transformers

The applicable winding(s) of the current and potential instrument transformers must:

- be approved by Measurement Canada for revenue metering.
- be burdened to a degree that does not compromise the accuracy required by this guideline.
- have an accuracy class rating that equals or exceeds the values specified in Appendix 4.

6.4 Remote Communications Equipment

The remote communications equipment may or may not be an integral part of the meter or the recorder. However, it must incorporate protocol schemes that will prevent the corruption of data during interval data transmission. The protocol must be suitable for the communications equipment type and nature of the communications media and path.

6.5 Quadrants To Be Measured

Generators exporting power onto the distribution system shall be equipped with bi-directional meters with four-quadrant measurement capability. An appropriate number of channels are required for four-quadrant meters to separately record active and reactive power in both the export and the import directions.

Where export of power is not required, unidirectional two-quadrant metering with at least two channels is required to separately record active and reactive power.

6.6 Password Protection

Two or more levels are required for each meter data collection agency. One level is for full access to set time functions and a second level is for read only access to interval data and event logs.

6.7 Safety Requirements

The installation shall conform to the requirements of:

- Measurement Canada Standard Drawings;
- CSA Standard – C22.2; and
- ANSI/IEEE C57.13.3-1983 *IEEE Guide for the Grounding of Instrument Transformer Secondary Circuits and Cases.*

7. INSPECTION

The Power Producer shall maintain a quality control and inspection program that is satisfactory to and approved by EDTI.

In addition to the Power Producer's normal inspection procedures, EDTI reserves the right to:

- witness the manufacturing, fabrication or any part of the work, which involves the subject equipment.
- inspect materials, documents, manufacturing operations and installation procedures.
- witness tests and to evaluate results of non-destructive examinations.

The Power Producer shall supply EDTI with a complete set of detailed drawings, which will be used by EDTI to assist in the inspection during the testing of the equipment.

8. TESTING

This section describes the test procedures and requirements for equipment used for the interconnection of generating facilities to EDTI's distribution system. Included are Type Testing, Commissioning Testing, and Periodic Testing. The procedures listed rely heavily on those described in appropriate Underwriters Laboratory (UL), Institute of Electrical and Electronic Engineers (IEEE), and International Electrotechnical Commission (IEC) documents, most notably:

- UL 1741 *Standard for Safety for Static Inverters and Charge Controllers for Use in Photovoltaic Power Systems*

- IEEE 929 *Recommended Practice For Utility Interface of Photovoltaic (PV) Systems*

8.1 GENERAL

The Power Producer shall notify EDTI in writing at least two weeks before the initial energizing and startup testing of the Power Producer's generating equipment and EDTI may witness the testing of any equipment and protective systems associated with the interconnection.

The tests described here are intended to provide assurance that the Power Producer's equipment will not adversely affect EDTI's distribution system and that a generating facility will cease providing power to EDTI's distribution system under abnormal conditions.

The following sections also describe the process for certifying equipment. Once a generating unit or device has been certified under this certification process, it may be considered to be suitable for use as part of a generating facility interconnected with EDTI's distribution system. Generally, EDTI will not require a Power Producer to repeat the design review or test the protective functions of equipment that has been certified. It should be noted the certification process is intended to facilitate the generating facility interconnections. Certification is not a prerequisite to interconnect a generating facility. The use of non-certified equipment may be acceptable to EDTI, subject to testing and approval by EDTI as discussed in section 8.2.

These test procedures only apply to the devices and packages associated with the protection of the interconnection between the generating system and EDTI's facilities. Interconnection protection is usually limited to voltage relays, frequency relays, synchronizing relays, reverse current or power relays, and anti-islanding schemes. The testing of relays or devices associated specifically with the protection or control of the generating equipment is recommended, but not required unless they impact the interconnection protection.

Testing of protection systems shall include procedures to functionally test all protective elements of the system up to and including tripping of the generator and/or point of common coupling. Testing will verify all protective set points and relay/breaker trip timing. The tests and testing procedures shall align with the requirements specified in IEEE P1547.

At the time of production, all interconnecting equipment and discrete relays must meet or exceed the requirements of ANSI/IEEE C62.41-1991 *Recommended Practice on Surge Voltages in Low- Voltage AC Power Circuits* or IEEE C37.90.1-1989 *Surge Withstand Capability (SWC) Tests for Protective Relays and Relay Systems.* If C62.41-1991 is used, the surge types and parameters shall be applied, as applicable, to the equipment's intended installation location.

8.2 CERTIFICATION CRITERIA

Equipment tested and approved (or listed) by an accredited, nationally recognized testing laboratory (NRTL) as having met the type testing requirements described in this document is considered to be 'Certified Equipment' for purposes of interconnection with EDTI's distribution system. Certification may apply to either a pre-packaged system or an assembly of components that address the necessary functions. Type testing may be done in the manufacturer's factory, a test laboratory, or in the field. At the discretion of the testing laboratory, field certification may apply only to the particular installation tested. In such cases, some or all of the tests may need to be repeated at other installations.

For non-certified equipment, some or all of the tests described in this document may be required by EDTI for each generating facility installation. The manufacturer, or another laboratory acceptable to EDTI, may perform these tests and the test results must be submitted for EDTI's review and approval. Approval by EDTI for equipment used in a particular application does not guarantee EDTI's approval for use in other applications.

When equipment is certified by a NRTL, the NRTL shall provide to the manufacturer, at a minimum, a certificate with the following information for each device:

A. Administrative

1) The effective date of certification or applicable serial number (range or first in series), and/or other proof that certification is current.
2) Equipment model number(s) of the certified equipment.
3) The software version utilized in the equipment, if applicable.
4) Test procedures specified (including date or revision number).
5) Laboratory accrEDTIitation (by whom and to what standard).

B. Technical (as appropriate)

1) Device ratings (kW, kVA, Volts, Amps, etc.).
2) Maximum available fault current in Amps.
3) In-rush current in Amps.
4) Trip points, if factory set (trip value and timing).
5) Trip point and timing ranges for adjustable settings.
6) Nominal power factor or range if adjustable.
7) If the device/system is certified for non-export and the method used (reverse power or under power).
8) If the device/system is certified as anti-islanding.

It is the responsibility of the equipment manufacturer to ensure that certification information is made publicly available by the manufacturer, the testing laboratory, or by a third party.

8.3 TYPE TESTING

Type testing is performed or witnessed once, by an independent testing laboratory for a specific protection package. Once a package meets the type test criteria described in this section, the design is accepted by EDTI. The type test must also determine if the protection settings meet the guidelines in this document. All interconnection equipment must include a type test procedure as part of the documentation. If any changes are made to the hardware, software, firmware, or verification test procedures, the manufacturer must notify the independent testing laboratory to determine what, if any, parts of the type testing must be repeated. Failure of the manufacturer to notify the independent test laboratory of changes may result in a withdrawal of approval and the disconnection of units installed since the change was made.

8.3.1 Inverters

Static power inverters, at the time of production, must meet or exceed all of the type tests and requirements appropriate for a utility interactive inverter as specified in UL 1741 and IEEE 929. These requirements may also be applied to inverters used with electric energy sources other than photovoltaic systems. All inverters must be anti-islanding as defined by IEEE 929.

Inverter devices must also pass the following additional type tests to:

- certify anti-islanding functions (section 8.3.4).
- certify export limit functions (section 8.3.5).
- determine the maximum in-rush current draw (section 8.3.6).
- verify the inverter's ability to synchronize (section 8.3.7).

8.3.2 Synchronous Generators

Synchronous generator devices must pass the following type tests to:

- certify anti-islanding functions (section 8.3.4).
- certify export limit functions (section 8.3.5).
- verify the generator's ability to synchronize (section 8.3.7).

8.3.3 Induction Generators

Induction generator devices must pass the following type tests to:

- certify anti-islanding functions (section 8.3.4).
- certify export limit functions (section 8.3.5).
- determine the maximum in-rush current draw (section 8.3.6).

8.3.4 Anti-Islanding Test

Interconnection protective devices must pass the anti-islanding test procedure described in section 8.4.1 and IEEE 929.

8.3.5 Export Limit Test

Interconnection protective devices must pass an export limit test. An example of a test procedure is included in Appendix 5, section *1. Export Limit Test Procedure*.

8.3.6 In-Rush Current Test

Generation equipment that utilizes EDTI system power to operate as a motor during startup must be tested to determine the maximum current drawn during this startup process. The resulting in-rush current is used to estimate the starting voltage drop. An example of a test procedure is included in Appendix 5, section *2. In-Rush Current Test Procedure*.

8.3.7 Synchronization Test

For synchronous generators and inverters capable of operating as a voltage source, a synchronization test must be performed to verify that the generator synchronizes within the specified voltage/frequency/phase angle requirements as described in section 4.2.2. An example of a test procedure is included in Appendix 5, section *3. Synchronization Test Procedure*.

8.4 Commissioning Testing

Commissioning testing of the Power Producer's generators and interconnection facilities will be performed prior to interconnection. As part of the commissioning process, the Power Producer shall provide EDTI with all test reports and the relay calibration reports for the generators and interconnection switchgear.

Commissioning testing, where required, will be performed onsite to verify protective settings and functionality as per EDTI relay test procedures. Upon initial parallel operation of a generating facility, or any time interconnection hardware or software is changed and may affect the functions listed below, a commissioning test must be performed by qualified personnel. Qualified personnel include professional engineers and certified technicians/licensed electricians with experience and training in testing protective equipment. Commissioning testing must be performed in accordance with the manufacturer's recommended test procedure to prove the settings and requirements of this document. EDTI has the right to witness commissioning tests as described below, or to require written certification by the installer describing which tests were performed and their results. Any exemptions, from performing a commissioning test, must be agreed upon in writing by EDTI.

Functions to be tested during commissioning, particularly with respect to non-certified equipment, may consist of the following:

1. Over and under voltage,
2. Over and under frequency,
3. Anti-islanding function (if applicable),
4. Export limit function (if applicable),
5. Inability to energize dead line,
6. Time delay on restart after utility source is stable,
7. Utility system fault detection (if used),
8. Synchronizing controls (if applicable),
9. Other interconnection protective functions that may be required as part of the *Interconnection Operating and Maintenance Agreement*.

Other checks and tests required to be performed, include:

10. Verifying final protective settings.
11. Trip test.
12. On-load test.

8.4.1 Certified Equipment

Generating facilities that are judged to have little or no potential impact on EDTI's distribution system need only incorporate certified equipment which, at a minimum, have passed their type tests. For such generating facilities, it is necessary to perform only the following tests:

1) Protection settings that have been changed after factory testing will require field verification. Tests will be performed using secondary injection, applied waveforms, a simulated utility, or, if none of the preceding tests are possible, a settings adjustment test, if the unit provides discrete readouts of the settings, to show that the device trips at the measured (actual) utility voltage or frequency.

2) The anti-islanding function, if provided, will be checked by operating a load break disconnect switch or circuit breaker to verify that the interconnection equipment ceases to energize its output terminals and does not restart for the required time delay after the switch is closed.

3) The export limit function will be tested using secondary injection techniques. Alternatively, this function may be tested by adjusting the generating facility output and local loads to verify that the applicable export limit criterion (such as reverse power or minimum power) is met.

The interconnection study may impose additional components or additional testing.

8.4.2 Non-Certified Equipment

Non-certified equipment shall be subject to the appropriate tests specified by EDTI. With EDTI's approval, these tests may be performed in the factory, in the field as part of commissioning, or a combination of both. EDTI, at its discretion, may also approve a reduced set of tests for a particular application or, for example, if EDTI determines that they have sufficient familiarity with the equipment.

8.4.3 Verification of Settings

If protective function settings have been adjusted as part of the commissioning process, then following the completion of such testing, the Power Producer shall confirm that all devices are set to EDTI approved settings. This step shall be documented in the Relay Operation Order certified by a Professional Engineer.

8.4.4 Trip Tests

Interconnection protective devices (e.g. reverse power relays) that have not previously been tested as part of the interconnection system with their associated interrupting devices (e.g. contactor or circuit breaker), shall be trip tested during commissioning. The trip test shall be adequate to prove that the associated interrupting devices open when the protective devices operate.

Interlocking circuits between protective devices and between interrupting devices shall be similarly tested unless they are part of a system that has been tested and approved during manufacture.

8.4.5 On-Load Tests

Interconnection protective devices that have not previously been tested as part of the interconnection system with their associated instrument transformers or that are wired in the field shall be given an on-load test during commissioning. This test will verify proper wiring, polarity, sensing signals, CT/PT ratios, and proper operation of the measuring circuits. The on-load test shall be made with the power system energized and carrying a known level of voltage and current. A measurement shall be made of the magnitude and phase angle of each AC voltage and AC current connected to the protective device and the results compared to expected values.

For protective devices with built in metering functions that report current and voltage magnitudes and phase angles, or magnitudes of current, voltage, and real and reactive power, the metered values can be compared to the expected values. Otherwise, calibrated portable ammeters, voltmeters, and phase-angle meters shall be used.

8.4.6 Switchgear and Metering

EDTI reserves the right to witness the testing of installed switchgear, and metering. The Power Producer shall notify EDTI at least 10 working days prior to any testing.

8.5 Periodic Testing

The periodical testing, calibration, and maintenance of generators and interconnection facilities shall be carried out in accordance with a maintenance schedule agreement between the Power Producer and EDTI. This includes the protective relaying, controls and automations. The Producer shall maintain periodic test reports or a log for inspection by EDTI. At the agreed intervals, the Producer shall submit to EDTI for their review the maintenance, test and calibration reports as a condition of continuing the interconnection agreement. EDTI may elect to check the setting and operation of the Producer's protective relaying under the aforesaid maintenance schedule agreement, as they deem appropriate.

Any system that depends upon a battery for trip power shall be checked and logged once per month for proper voltage, or monitored continuously.

9. DATA REQUIREMENTS

The following is a list of the drawings and data required for approval of the project.

Drawing/Data	Proposal	Approval*	Verified
Manufacturer's Equipment Data Sheet			X
Control schematic		X	X
Single Line Diagram indicating proposed protection settings	X	X	X
Description of Protection Scheme	X	X	X
Generator Nameplate schedule		X	X
Fuse and protective relay coordination study & settings		X	X
Current transformer characteristic curve		X	X
Commissioning Report, complete with Protection Settings			X
Plot plan showing location of lockable, "visible" disconnect device	X	X	X

*The minimum time requirement for review of information will generally be 10 working days.

10. MARKING AND TAGGING

The nameplate on switchgear shall include the following information:

- Manufacturer's name
- Manufacturer's serial number
- The disconnect switch shall be clearly marked "DG Disconnect Switch" and tagged with an approved identification number from EDTI.

11. MAINTENANCE

The Power Producer is fully responsible for:

- all routine maintenance of the generator, control and protective equipment and the keeping of records for such maintenance.
- maintaining the equipment on their side of the PCC to accepted industry standards, in particular the Canadian Electrical Code (CEC) Part 1, Rule 2-300.

The Power Producer shall present to EDTI the planned maintenance procedures and a maintenance schedule for the interconnection protection equipment. Failure to maintain Canadian Electrical Code and industry acceptable facilities and maintenance standards can result in the disconnection of the generator.

Maintenance on EDTI's distribution system will be carried out according to EDTI's distribution maintenance procedures and schedules.

Details on maintenance responsibilities will be outlined in the *Interconnection Operating and Maintenance Agreement* to be signed by both EDTI and the Power Producer.

12. TABLES

TABLE 1 – PROTECTION FOR SINGLE-PHASE GENERATORS

Interconnection Control, Protection and Safety Equipment[1]

Single-Phase Connected to Secondary System

X denotes a requirement for this *Guideline*

GENERATOR SIZE	
50 kW or Less[3]	
Interconnect Disconnect Device	X
Generator Disconnect Device	X
Undervoltage Trip	X
Overvoltage Trip	X
Over & Under Frequency Trip	X
Overcurrent	X
Synchronizing Control[2]	Manual or Automatic
Synch-Check[2] (At PCC)	X

Notes:

1. Exporting to EDTI's System may require additional operational/protection devices and will require coordination of operations with EDTI.
2. For synchronous and other types of generators with stand alone capability.
3. For single-phase generators larger than 50 kW, consult with EDTI on the required interconnection control, protection and safety equipment.

TABLE 2 – PROTECTION FOR THREE-PHASE GENERATORS

Interconnection Control, Protection and Safety Equipment[8]

Three-Phase Connected to Primary or Secondary System

X denotes a requirement for this *Guideline*.
All devices are three-phase unless otherwise specified.

Device #	Generator Size Classifications:	SMALL		MEDIUM		LARGE
	Device	< 50 kW	50 to 499 kW	500 to 2,000 kW	2,001 to 10,000 kW	≥ 10,000 kW
	Interconnect Disconnect Device	X	X	X	X	X
	Generator Disconnect Device	X	X	X	X	X
	Synchronizing Control[1] Manual (M) or Automatic (A)	M or A	M or A	A	A	A
25	Synch-Check[1] (At Point of Common Coupling)	X	X	X	X	X
	Automatic Voltage Regulation (AVR)[1]				X	X
27	Undervoltage	X	X	X	X	X
59	Overvoltage	X	X	X	X	X
59N	Neutral Overvoltage[2]	X[3]	X	X	X	X
50/51	Instantaneous/Timed Overcurrent	X[4]	X[4]	X[4]	X[4]	X[4]
50/51N	Instantaneous/Timed Neutral Overcurrent	X[3]	X	X	X	X
81	Over and Under Frequency	X	X	X	X	X
32	Directional Power	X[5]	X[5]	X[5]	X[5]	X[5]
TT	Transfer Trip or Equivalent Relay		X[6]	X[6]	X[6]	X[6]
	Telemetry Data Communication			X[7]	X[7]	X
	Anti-Islanding for Inverters (IEEE Std. 929, UL 1741)	X	X	X	X	X

TABLE 2 – NOTES

Interconnection Control, Protection and Safety Equipment[8]

Three-Phase Connected to Primary or Secondary System

Notes:

1. For synchronous and other types of generators with stand alone capability.

2. Only required for generators that have their interconnection transformer's primary winding ungrounded. Used in conjunction with three PT's in broken delta configuration rated for line-to-line voltage. For detecting ground faults on the distribution system.

3. May not be required if the generator is an inverter type voltage-following system of less than 50 kW aggregate. In this case, EDTI will inform the Power Producer if this protection is required.

4. A timed overcurrent relay with voltage restraint (51V) may also be required to prevent nuisance trips.

5. Only required for non-exporting or export limited generators.

6. Transfer trip or equivalent protective relay function required for all synchronous generators rated 500 kW and larger with export capability. May also be required for exporting synchronous generators under 500 kW, depending upon characteristics of the distribution circuit. EDTI will advise.

7. System Controller requirement for all generators 5 MW and larger. EDTI may also require telemetry for smaller generators depending upon location and distribution circuit characteristics.

8. Exporting to EDTI's System may require additional operational/protection devices and will require coordination of operations with EDTI.

TABLE 3 – PROTECTION FOR CLOSED TRANSITION SWITCHING

Interconnection Control, Protection and Safety Equipment

Generators Connected to Primary or Secondary System

For 30 Cycles or Less

(Closed Transition Switching)

X denotes a requirement for this *Guideline*

GENERATOR SIZE	
10 MW or Less_	
Interconnect Disconnect Device	X
Generator Disconnect Device	X
Undervoltage Trip	X
Overvoltage Trip	X
Over & Under Frequency Trip	X
Overcurrent	X
Neutral Overvoltage Trip[1] Or Neutral Overcurrent Trip[1]	X
Directional Power Trip	X
Synchronizing Control[2]	Manual or Automatic
Synch-Check[2] (At PCC)	X

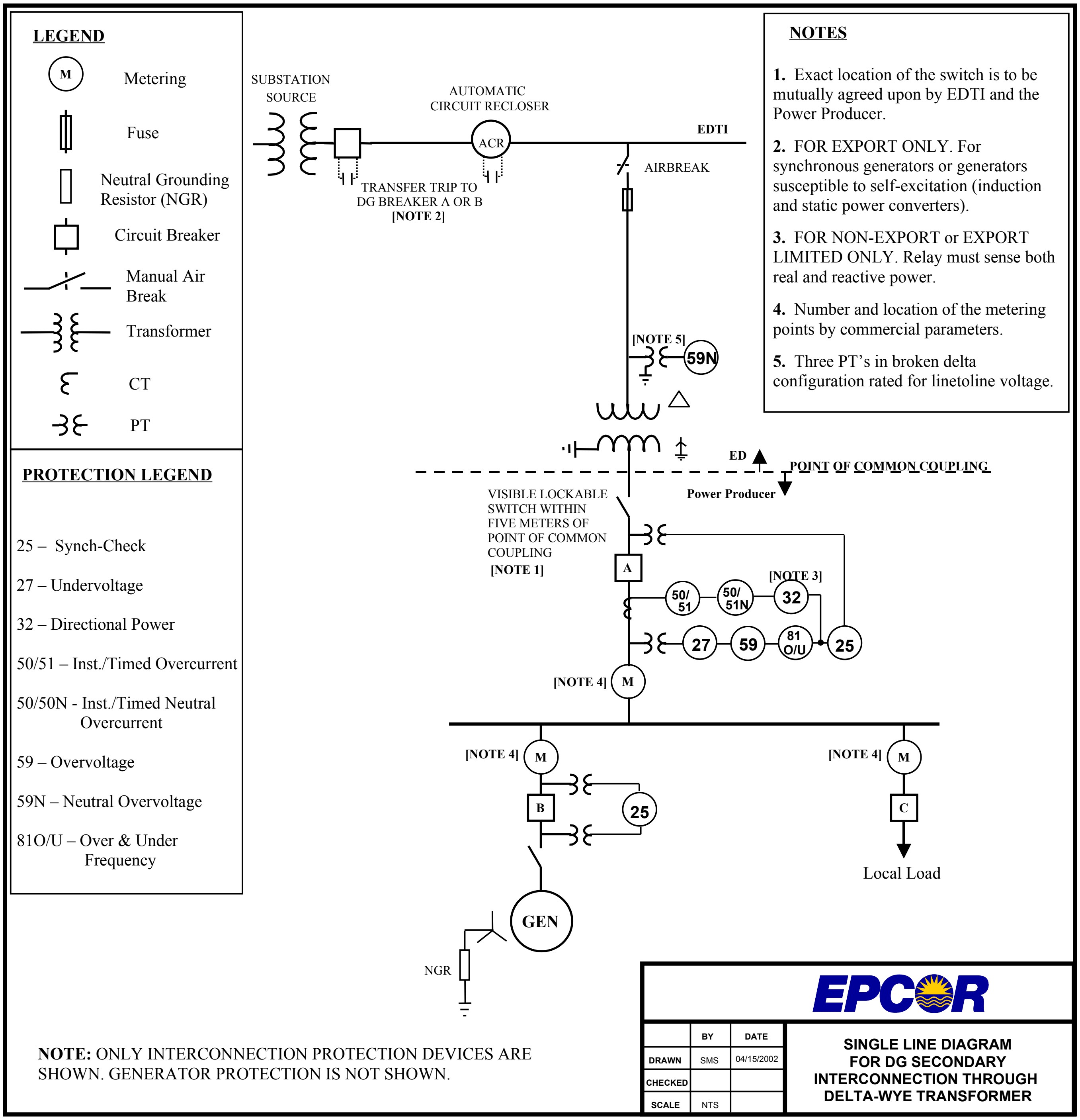
Notes:

1. Selection depends upon grounding connection of interconnection transformer.
2. For synchronous and other types of generators with stand alone capability.

APPENDIX DOCUMENTS

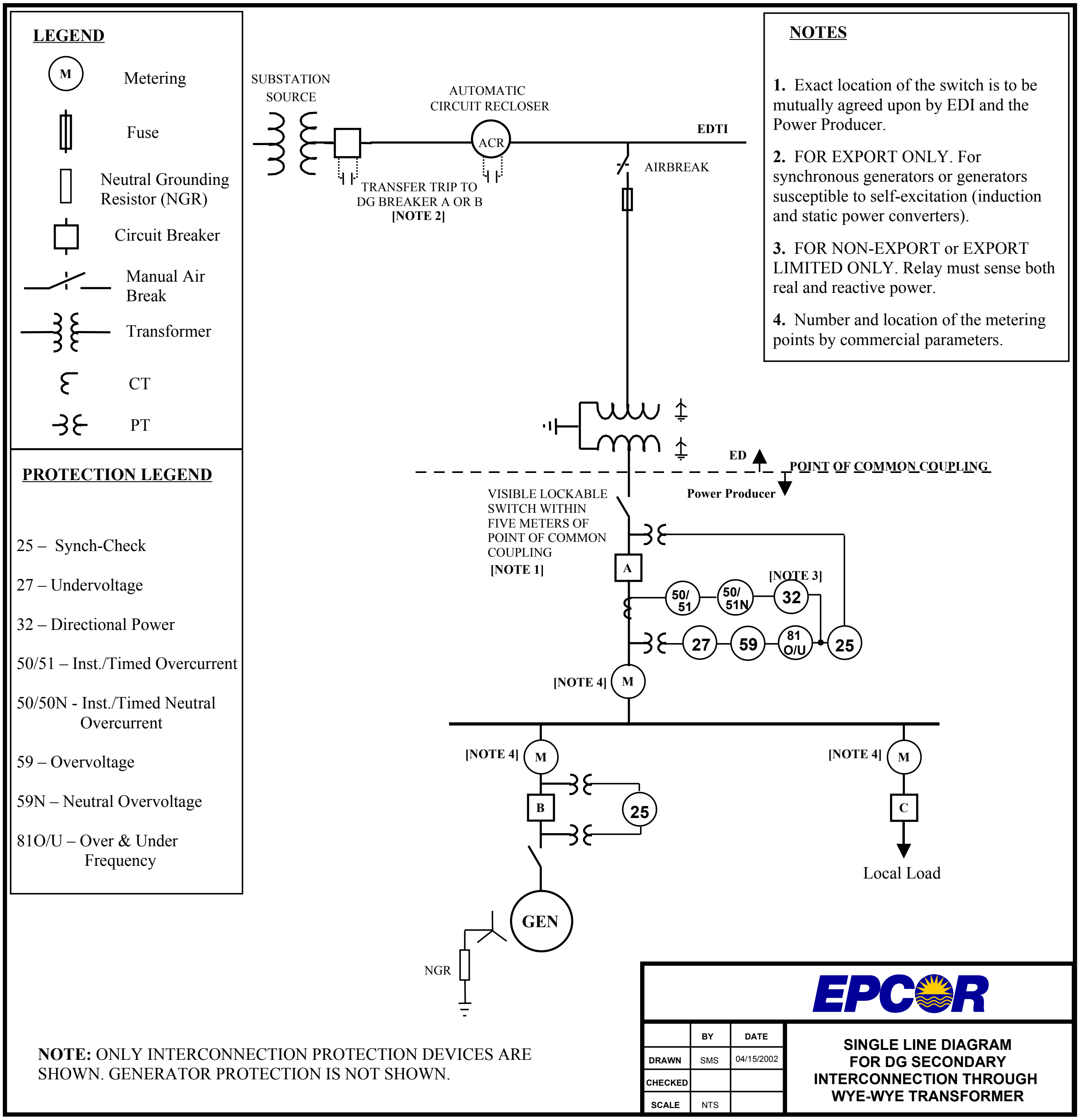
APPENDIX 1 – SINGLE LINE DIAGRAM FOR DELTA-WYE SECONDARY INTERCONNECTION

(EXAMPLE ONLY)



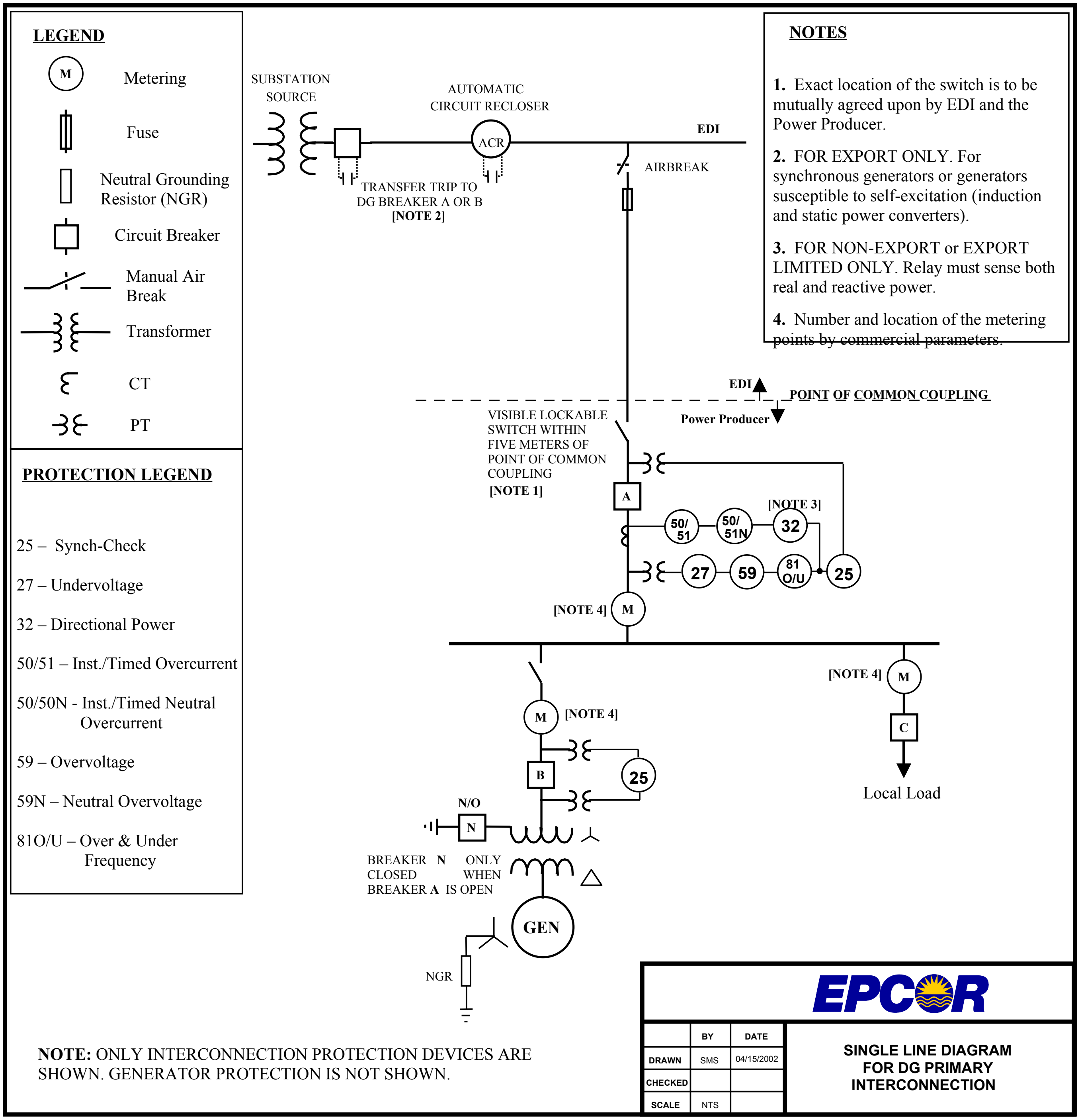
APPENDIX 2 – SINGLE LINE DIAGRAM FOR WYE-WYE SECONDARY INTERCONNECTION

(EXAMPLE ONLY)



APPENDIX 3 – SINGLE LINE DIAGRAM FOR PRIMARY INTERCONNECTION

(EXAMPLE ONLY)



APPENDIX 4 – SCHEDULE OF ACCURACIES FOR METERING EQUIPMENT

SCHEDULE OF ACCURACIES FOR METERING EQUIPMENT APPROVED UNDER SECTION 9(1) OF THE ELECTRICITY AND GAS INSPECTION ACT

Metering Point Capacity (MVA)	Watt-hour Meter Accuracy Class	Varhour Meter Accuracy Class	Measurement Transformers Accuracy Class
10 and Above	0.2%	0.5%	0.3%
Below 10	0.5%	1.0%	0.3%

Notes:

1. The columns apply to requirements set out in this guideline under Metering sections 6.2 & 6.3.
2. If an alternate measurement is used to determine reactive energy, the accuracy class of the alternate measurement must be equal to or better than the accuracy class set out for reactive energy.

APPENDIX 5 – EXAMPLE TEST PROCEDURES

1. Export Limit Test Procedure[1]

The export limit test is intended to verify the operation of relays, controllers and inverters designed to limit the export of power and certify the equipment as meeting the requirements of an export limited distributed generation facility. Tests are provided for discrete relay packages and for controllers and inverters that include the intended function.

A) Reverse Power Relay Test

This version of the export limit test procedure is intended for stand alone reverse power and under power relay packages provided to meet the requirements of an export limited distributed generation facility. It should be understood that in the reverse power application, the relay will provide a trip output with power in the export direction (toward the EDTI distribution system).

Step 1: Power Flow Test at Minimum, Midpoint and Maximum Pickup Level Settings

Determine the appropriate secondary pickup current for the desired export power flow of 0.5 secondary watts (the agreed upon minimum pickup setting, assumes 5 Amp and 120V CT/PT secondary). Apply nominal voltage with minimum current setting at zero (0) degrees in the trip direction. Increase the current to pickup level. Observe the relay trip's (LCD or computer display) indication of power values. Note the indicated power level at which the relay trips. The power indication should be within 2 percent of the expected power. For relays with adjustable settings, repeat this test at the midpoint, and maximum settings. Repeat at phase angles of 90, 180 and 270 degrees and verify that the relay does **not** operate (measured watts will be zero or negative).

Step 2: Leading Power Factor Test

Apply rated voltage to the relay with a minimum pickup current setting (calculated value for system application) and apply a leading power factor load current in the non-trip direction (current lagging voltage by 135 degrees). Increase the current to the relay rated current and verify that the relay does **not** operate. For relays with adjustable settings, this test should be repeated at the minimum, midpoint, and maximum settings.

Step 3: Minimum Power Factor Test

At nominal voltage and with the minimum pickup (or ranges) determined in *Step 1*, adjust the current phase angle to 84 or 276 degrees. Increase the current level to pickup (about 10 times higher than at 0 degrees) and verify that the relay operates. Repeat for phase angles of 90, 180 and 270 degrees and verify that the relay does **not** operate.

1. <u>EXPORT LIMIT TEST PROCEDURE</u> ***<u>(Continued)</u>***

A) Reverse Power Relay Test *(Continued)*

Step 4: Negative Sequence Voltage Test

Using the pickup settings determined in *Step 1*, apply rated relay voltage and current at 180 degrees from tripping direction, to simulate normal load conditions (for three-phase relays, use Ia at 180, Ib at 60 and Ic at 300 degrees). Remove Phase-1 voltage and observe that the relay does **<u>not</u>** operate. Repeat for phases 2 and 3.

Step 5: Load Current Test

Using the pickup settings determined in *Step 1*, apply rated voltage and current at 180 degrees from the tripping direction, to simulate normal load conditions (use Ia at 180, Ib at 300 and Ic at 60 degrees). Observe that the relay does **<u>not</u>** operate.

Step 6: Unbalanced Fault Test

Using the pickup settings determined in *Step 1*, apply rated voltage and 2 times rated current, to simulate an unbalanced fault in the non-trip direction (use Va at 0 degrees, Vb and Vc at 180 degrees, Ia at 180 degrees, Ib at 0 degrees, and Ic at 180 degrees). Observe that the relay, especially single-phase, does **<u>not</u>** operate.

Step 7: Time Delay Settings Test

Apply *Step 1* settings and set the time delay to the minimum setting. Adjust the current source to the appropriate level to determine operating time, and compare against calculated values. Verify that the timer stops when the relay trips. Repeat at midpoint and maximum delay settings.

Step 8: Dielectric Test

Perform the test described in IEC 414 using 2 kV RMS for 1 minute.

Step 9: Surge Withstand

Perform the surge withstand test described in IEEE C37.90.1.

1. Export Limit Test Procedure *(Continued)*

B) Under-Power Relay Test

In the under-power application, the relay will provide a trip output when import power (toward the Producer's generating facility) drops below the specified power level.

Note: For an under-power relay, pickup is defined as the highest power level at which the relay indicates that the power is **less** than the approved setting.

Step 1: Power Flow Test at Minimum, Midpoint and Maximum Pickup Level Settings

Determine the appropriate secondary pickup current for the desired power flow pickup level of 5% of peak load (the agreed upon minimum pickup setting). Apply rated voltage and current setting at 0 degrees in the direction of normal load current.

Decrease the current to pickup level. Observe the relay's (LCD or computer display) indication of power values. Note the indicated power level at which the relay trips. The power indication should be within two (2) percent of the expected power. For relays with adjustable settings, repeat the test at the midpoint, and maximum settings. Repeat at phase angles of 90, 180 and 270 degrees and verify that the relay operates properly.

Step 2: Leading Power Factor Test

Using the pickup current setting determined in *Step 1*, apply rated voltage and rated leading power factor load current in the normal load direction (current leading voltage by 45 degrees). Decrease the current to 145% of the pickup level determined in *Step 1* and verify that the relay does **not** operate. For relays with adjustable settings, repeat the test at the minimum, midpoint, and maximum settings.

Step 3: Minimum Power Factor Test

At nominal voltage and with the minimum pickup (or ranges) determined in *Step 1*, adjust the current phase angle to 84 or 276 degrees. Decrease the current level to pickup (about 10% of the value at 0 degrees) and verify that the relay operates. Repeat for angles 90, 180 and 270 degrees and verify that the relay operates for any current less than rated current.

1. Export Limit Test Procedure *(Continued)*

B) Under-Power Relay Test *(Continued)*

Step 4: Negative Sequence Voltage Test

Using the pickup settings determined in *Step 1*, apply rated relay voltage and 25% of rated current in the normal load direction, to simulate light load conditions. Remove Phase-1 voltage and observe that the relay does **not** operate, repeat for phases 2 and 3.

Step 5: Unbalanced Fault Test

Using the pickup settings determined in *Step 1*, apply rated voltage and 2 times rated current, to simulate an unbalanced fault in the normal load direction (use Va at 0 degrees, Vb and Vc at 180 degrees, Ia at 0 degrees, Ib at 180 degrees, and Ic at 0 degrees). Observe that the relay, especially single phase, operates properly.

Step 6: Time Delay Settings Test

Apply *Step 1* settings and set the time delay to minimum setting. Adjust the current source to the appropriate level to determine operating time, and compare against calculated values. Verify that the timer stops when the relay trips. Repeat at midpoint and maximum delay settings.

Step 7: Dielectric Test

Perform the test described in IEC 414 using 2 kV RMS for 1 minute.

Step 8: Surge Withstand

Perform the surge withstand test described in IEEE C37.90.1.

C) Functional Tests For Inverters and Controllers

Inverters and controllers designed to provide reverse or under power functions shall be tested to certify the intended operation of this function. Two methods are provided:

Method 1: If the controller utilizes external current/voltage measurement to determine the reverse or under-power condition, then the controller shall be functionally tested by application of appropriate secondary currents and potentials as described above in *1. A) Reverse Power Relay Test.*

Method 2: If external secondary current or potential signals are not used, then unit specific tests must be conducted to verify that power cannot be exported across the Point of Common Coupling for a period exceeding two seconds. These tests may be factory tests, if the measurement and control points are part of a single unit, or may be provided for in the field.

2. In-Rush Current Test Procedure[1]

This test will determine the maximum in-rush current drawn by the unit. Two methods are provided:

a) Locked-Rotor Method

Use the test procedure defined in NEMA MG 1 (manufacturer's data is acceptable if available).

b) Start Up Method

Install and setup the generating facility equipment as specified by the manufacturer. Using a calibrated oscilloscope or data acquisition equipment with appropriate speed and accuracy, measure the current draw at the Point of Common Coupling as the generating facility starts up and parallels with EDTI's distribution system. Startup shall follow the normal, manufacturer specified procedure. Sufficient time and current resolution and accuracy shall be used to capture the maximum current draw within five percent. In-rush current is defined as the maximum current draw from EDTI during the startup process, using a 10 cycle moving average. During the test, the utility source, real or simulated, must be capable of maintaining voltage within +/- five percent of rated at the connection to the unit under test. Repeat this test five times. Report the highest 10 cycle current as the in-rush current. A graphical representation of the time-current characteristic along with the certified in-rush current must be included in the test report and made available to EDTI.

3. Synchronization Test Procedure[1]

This test verifies that the unit synchronizes within the specified voltage/frequency/phase angle requirements.

The test will start with only one of the three parameters: 1) voltage difference between the generating facility and EDTI's distribution system, 2) frequency difference, or 3) phase angle outside of the synchronization specification.

Initiate the synchronization routine and verify that the generating facility is brought within specification prior to synchronization. Repeat the test five times for each of the above three parameters. For manual synchronization with synch-check relay or manual control with auto-synchronization relay, the test must verify that paralleling does not occur until the parameters are brought within specifications.

[1] Reference: Pacific Gas and Electric Company, Rule 21 – Generating Facility Interconnections, January 5, 2001.

APPENDIX 6 – REFERENCE NOTES

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Note 1:

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d) Westinghouse. "Electrical Transmission & Distribution Reference Book" published by Westinghouse Electric Corporation, East Pittsburgh, Pa.

Note 2:

a) Blackburn, J. Lewis. "Protective Relaying, Principles and Applications" published by Marcel Dekkar Inc., 1987.

b) Westinghouse. "Electrical Transmission & Distribution Reference Book" published by Westinghouse Electric Corporation, East Pittsburgh, Pa.

Note 3:

a) Westinghouse. "Electric Utility Reference Book", Chapter 8, Harmonic and Resonant Effects on Application of Capacitors, published by Westinghouse Electric Corporation, East Pittsburgh, Pa.

b) Sturton, A.B. "Connecting Small Generators to Utility Distribution Systems" CEA Report 128 D 767, Chapters 11 and 12, published by Canadian Electrical Association, June 1994.

c) Weedy, B.M. "Electric Power Systems" 2nd Edition, Chapter 10, page 380 "Switching surges - interruption of capacitive circuits", published by John Wiley & Sons, Inc.

Note 4:

a) Sturton, A.B. "Connecting Small Generators to Utility Distribution Systems" CEA Report 128 D 767, Chapter 4, published by Canadian Electrical Association, June 1994.

APPENDIX 7 – APPLICABLE CODES AND STANDARDS

APPLICABLE CODES AND STANDARDS

When the stated version of the following standards is superseded by an approved revision, then that revision shall apply.

The generator or distributed resource interconnection shall conform to this guideline and to the applicable sections of the following codes and standards. Specific types of interconnection schemes, distributed resource technologies, and distribution systems may have additional requirements, standards, recommended practices, or guideline documents external to this guideline. The applicability and hierarchy of those, with respect to the requirements herein, are beyond the scope of this guideline. **This list of standards is therefore not to be regarded as all-inclusive**.

Power Quality Standards

CSA Standard CAN3-C235-83 (R2000) - Preferred Voltage Levels for AC Systems, 0 to 50 000 V

ANSI C84.1-1989 American National Standards for Electric Power Systems and Equipment Ratings (60 Hertz). Establishes nominal voltage ratings and operating tolerances for 60 Hz electric power systems from 100 V through 230 kV

IEEE Std 493-1997 IEEE Recommended Practice for Design of Reliable Industrial and Commercial Power Systems (IEEE Gold Book). Chapter 9 deals specifically with voltage sags analysis and methods of reporting sag characteristics graphically and statistically.

IEEE Std 519-1992 IEEE Recommended Practice and Requirements for Harmonic Control in Electric Power Systems

IEEE Std 1100-1999 IEEE Recommended Practice for Powering and Grounding Sensitive Electronic Equipment (IEEE Emerald Book)

IEEE Std 1159-1995 IEEE Recommended Practice for Monitoring Electric Power Quality

IEEE Std 1250-1995 IEEE Guide for Service to Equipment Sensitive to Momentary Voltage Disturbances

In addition to the power quality standards, the following standards are applicable to the interconnection of distributed resources on EDTI's distribution system:

Alberta Electrical and Communication Utility Code (formerly the Alberta Electrical and Communication Utility System Regulation 44/1976 or future amendments).

Canadian Electrical Code, CSA - C22.1, latest version

Can/CSA - C22.2 No. 31-M89 (R2000) - Switchgear Assemblies

Can/CSA - C22.2 No. 107.1-95 (R2000) – General Use Power Supplies

Can/CSA - C22.2 No. 1010.1-92 (R1999) - Safety Requirements for Electrical Equipment for Measurement, Control and Laboratory Use – Part 1:General Requirements

Can/CSA - C22.2 No. 144-M91 (R1997) - Ground Fault Circuit Interrupters

Can/CSA - C22.2 No. 193-M1983 (R1992) – High-Voltage Full-Load Interrupter Switches

Can/CSA C22.2 No. 201-M1984 (R1992) – Metal- Enclosed High Voltage Busways

Can/CSA C22.2 No. 229-M1988 (R2000) - Switching and Metering Centres

IEEE P1547 DRAFT Standard for Interconnecting Distributed Resources with Electric Power Systems

IEEE Std 80–2000 IEEE Guide for Safety in AC Substation Grounding

IEEE Std 100-1996 IEEE Standard Dictionary of Electrical and Electronics Terms

IEEE Std 120-1989 (R1997) IEEE Master Test Guide for Electrical Measurements in Power Circuits

IEEE Std 242-2001 IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems *(IEEE Buff Book)*

IEEE Std 315-1975 (R1993) ANSI Y32.3-1975 (R1989) CSA Z99-1975 Graphic Symbols for Electrical and Electronics Diagrams (Including Reference Designation Letters)

IEEE Std 929-2000 IEEE Recommended Practice for Utility Interface of Photovoltaic (PV) Systems

IEEE Std 1291-1993 (R1998) IEEE Guide for Partial Discharge Measurements in Power Switchgear

C12.20 – American National Standard for Electricity Meters 0.2% And 0.5% Accuracy Classes

C37.04-1999 IEEE Standard Rating Structure for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis (ANSI/DoD)

C37.06-1997 American National Standard for Switchgear--AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis--Preferred Ratings and Related Required Capabilities

C37.09-1999 IEEE Standard Test Procedure for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis (ANSI/DoD)

C37.010-1999 IEEE Application Guide for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis

C37.011-1994 IEEE Application Guide for Transient Recovery Voltage for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis

C37.012-1979 (R2000) IEEE Application Guide for Capacitance Current Switching for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis

C37.013-1997 IEEE Standard for AC High-Voltage Generator Circuits Breaker Rated on a Symmetrical Current Basis

C37.015-1993 IEEE Application Guide for Shunt Reactor Switching

C37.081-1981 (R1988) Guide for Synthetic Fault Testing of AC High-Voltage Circuit Breakers Rated on a Symmetrical Current basis

C37.1-1987 ANSI/IEEE Standard Definition, Specification and Analysis of Systems Used for Supervisory Control, Data Acquisition, and Automatic Control

C37.2-1996 IEEE Standard Electrical Power System Device Function Numbers

C37.11-1997 IEEE Standard Requirements for Electrical Control for High-Voltage Circuit Breakers Rated on A Symmetrical Current Basis

C37.13-1990 (R1995) IEEE Standard for Low-Voltage AC Power Circuit Breakers Used in Enclosures

C37.14-1992 IEEE Standard for Low-Voltage DC Power Circuit Breakers Used in Enclosures

C37.16-1997 American National Standard for Switchgear - Low-Voltage Power Circuit Breakers and AC Power Circuit Protectors - Preferred Ratings, Related Requirements, and Application Recommendations

C37.18-1979 (R1996) ANSI/IEEE Standard Enclosed Field Discharge Circuit Breakers for Rotating Electric Machinery

C37.20.1-1993 ANSI/IEEE Standard for Metal-Enclosed Low-voltage Power Circuit Breakers Switchgear

C37.20.2-1999 IEEE Standard for Metal-Clad and Station-Type Cubicle Switchgear

C37.20.3-2001 ANSI/IEEE Standard for Metal-Enclosed Interrupter Switchgear

C37.20.6-1997 IEEE Standard for 4.76 to 38 kV Rated Grounding and Testing Devices used in Enclosures

C37.23-1987 (R1991) IEEE Standard for Metal-Enclosed Bus and Calculating Losses in Isolated-Phase Bus

C37.24-1986 (R1998) ANSI/IEEE Guide for Evaluating the Effect of Solar Radiation on Outdoor Metal-Enclosed Switchgear

C37.27-1987 (R1998) ANSI/IEEE Standard Application Guide for Low-voltage AC Nonintegrally Fused Power Circuit Breakers (Using Separately Mounted Current-Limiting Fuses)

C37.29-1981 ANSI/IEEE Standard for Low-voltage AC Power Circuit Protectors Used in Enclosures

C37.30-1997 IEEE Standard Requirements for High-Voltage Switches

C37.32-1996 American National Standard for Switchgear--High-Voltage Air Switches, Bus Supports, and Switch Accessories--Schedules of Preferred Ratings, Manufacturing Specifications, and Application Guide

C37.34-1994 IEEE Standard Test Code for High-Voltage Air Switches

C37.35-1995 IEEE Guide for the Application, Installation, Operation, and Maintenance of High-Voltage Air Disconnecting and Load Interrupter Switches

C37.36b-1990 IEEE Guide to Current Interruption with Horn-Gap Air Switches

C37.37-1996 IEEE Standard for Loading Guide for AC High-Voltage Air Switches (in Excess of 1000 V)

C37.38-1989 IEEE Standard for Gas-Insulated, Metal-Enclosed Disconnecting, Interrupter, and Grounding Switches

C37.42-1996 American National Standard for Switchgear--Distribution Cutouts and Fuse Links--Specifications

C37.44-1981 (R1987) American National Standard Specifications for Distribution Oil Cutouts and Fuse Links

C37.50-1989 American National Standard Test Procedures for Low-voltage AC Circuit Breakers Used in Enclosures

C37.51-1989 American National Standard Conformance Test Procedure for Metal Enclosed Low-voltage AC Power Circuit-Breaker Switchgear Assemblies

C37.52-1974 (R1989) American National Standard Test Procedures for Low-voltage AC Power Circuit Protectors Used in Enclosures

C37.54-1996 American National Standard for Switchgear--Indoor Alternating-Current High-Voltage Circuit Breakers Applied as Removable Elements in Metal-Enclosed Switchgear Assemblies--Conformance Test Procedures

C37.55-1989 American National Standard for Switchgear--Metal-Clad Switchgear Assemblies--Conformance Test Procedures

C37.57-1990 American National Standard for Switchgear--Metal-Enclosed Interrupter Switchgear Assemblies--Conformance Testing

C37.58 American National Standard Conformance Test Procedures for Indoor AC Medium Voltage Switches for use in Metal-Enclosed Switchgear

C37.66-1969 (Reaff 1988) American National Standard for Requirements for Oil-Filled Capacitor Switches for Alternating-Current Systems

C37.81-1989 (R1999) IEEE Guide for Seismic Qualification of Class 1E Metal-Enclosed Power Switchgear Assemblies

C37.85-1989 (R1998) American National Standard for Switchgear--Alternating-Current High-Voltage Power Vacuum Interrupters-Safety Requirements for X-Radiation Limits

C37.90-1989 (R1994) ANSI/IEEE Standard for Relays and Relay Systems Associated with Electric Power Apparatus

C37.90.1-1989 (R1994) ANSI/IEEE Standard Surge Withstand Capability (SWC) Tests for Protective Relays and Relay Systems

C37.90.2-1995 (R2001) ANSI/IEEE Standard Withstand Capability of Relay Systems to Radiated Electromagnetic Interference from Transceivers

C37.95-1989 (R1994) IEEE Guide for Protective Relaying of Utility Consumer Interconnections

C37.98-1987 (R1990) ANSI/IEEE Standard for Seismic Testing of Relays

C57.12.00-2000 IEEE Standard General Requirements for Liquid Immersed Distribution, Power and Regulating Transformers

C57.12.13-1982 Conformance Requirements for Liquid Filled Transformers Used in Unit Installations including Unit Substations

C57.13-1993 IEEE Standard Requirements for Instrument Transformers

C57.13.1-1981 (R1999) IEEE Guide for Field Testing of Relaying Current Transformers

C57.13.2-1991 IEEE Standard Conformance Test Procedures for Instrument Transformers

C57.13.3-1983 (R1990) IEEE Guide for the Grounding of Instrument Transformer Secondary Circuits and Cases

C57.19.100-1995 IEEE Guide for Application of Power Apparatus Bushings

C57.98-1993 IEEE Guide for Transformer Impulse Tests

C57.110-1986 (R1992) IEEE Recommended Practice for Establishing Transformer Capability When Supplying Nonsinusoidal Load Currents

C62.1-1989 (R1994) – IEEE Standard for Gapped Silicon-Carbide Surge Arresters for AC Power Circuits

C62.11-1999 – IEEE Standard for Metal-Oxide Surge Arresters for AC Power Circuits

C62.23-1995 IEEE Application Guide for Surge Protection of Electric Generating Plants

C62.41-1991 (R1995) IEEE Recommended Practice on Surge Voltages in Low-Voltage AC Power Circuits

C62.45-1992 (R1997) IEEE Guide on Surge Testing for Equipment Connected to Low-Voltage AC Power Circuits

C62.92.1-2000 IEEE Guide for the Application of Neutral Grounding in Electrical Utility Systems, Part I – Introduction

C62.92.2-1989 (R2000) IEEE Guide for the Application of Neutral Grounding in Electrical Utility Systems, Part II – Grounding of Synchronous Generator Systems

APPENDIX 7 – APPLICABLE CODES AND STANDARDS *(Continued)*

C62.92.3-1993 (R2000) IEEE Guide for the Application of Neutral Grounding in Electrical Utility Systems, Part III – Generator Auxiliary Systems

C62.92.4-1991 (R1996) IEEE Guide for the Application of Neutral Grounding in Electrical Utility Systems, Part IV – Distribution

IEC 414-1973 Safety Requirements for Indicating and Recording Electrical Measuring Instruments and Their Accessories

IEC 61000-3-3 Limitation of voltage fluctuations and flicker in low-voltage supply systems for equipment with rated current less than 16A

IEC 61000-3-5 Limitation of voltage fluctuations and flicker in low-voltage supply systems for equipment with rated current greater than 16A

UL 1008 Transfer Switch Equipment

UL 1741-2000 Standard for Safety for Static Inverters and Charge Controllers for Use in Photovoltaic Power Systems

NEMA Standards Publication No. CC 1 - Electric Power Connectors for Substations

NEMA Standards Publication No. LA 1 - Surge Arresters

NEMA Standards Publication No. MG 1 - Motors and Generators