

# Interconnection Requirements

*Generating Facilities > 100 kW*

*(Connected to Distribution Systems Rated  $\leq 26,400$  V)*

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## 1. Purpose

This document states the minimum requirements for safe and effective operation of the Interconnection Customer's Generating Facility interconnected (paralleled) with the Nova Scotia Power Inc. (NS Power) Distribution System. This document describes NS Power's interconnection requirements as well as the minimum design and performance standards the Interconnection Customer must satisfy, and a range of normal, abnormal and emergency system conditions the Generating Facility and the Interconnection Customer's Interconnection Facilities could encounter while connected to the Distribution System.

This document is based on the following assumptions and principles:

- (a) The Generating Facility and the Interconnection Customer's Interconnection Facilities meet the installation requirements of the Canadian Electrical Code Part 1 and equipment is certified to relevant Part 2 product standards. Other local and provincial construction and installation regulations may also apply to the Interconnection Customer's facilities.
- (b) Safety of personnel, the public and equipment is of primary concern in the design of the interconnected systems.
- (c) Interconnection Customers will discuss project plans with NS Power before purchasing or installing equipment, as requirements will vary depending on capacity, type, location and existing NS Power Distribution System configuration.

NS Power reserves the right to amend any of these requirements at any time.

The Interconnection Customer is responsible for making required changes to the Interconnection Customer's Interconnection Facilities to meet new or revised standards and documents judged applicable by NS Power. The Interconnection Customer shall make all required changes in a timely manner. The Interconnection Customer is responsible for all costs associated with such changes.

### **1.1. Interconnection of Distribution Generation**

An Interconnection Customer shall be permitted to operate three phase, 60 Hertz generating equipment interconnected with the Distribution System, provided the Interconnection Customer and their facilities meet or exceed the requirements of NS Power's interconnection documents and supporting interconnection and operating agreements. Implementing the requirements of this document will help ensure that the Interconnection Customer's facilities do not operate in a manner that would compromise the safe operation, reliability or power quality of the Distribution System.

The Interconnection Customer is required to install, operate, and maintain its facilities in good order and repair at all times (in conformity with good industry practice) to ensure safe and reliable parallel operation with the Distribution System. Agreement to and execution of the "Standard Small Generator Interconnection Agreement (SSGIA)"<sup>1</sup> between the Interconnection Customer and NS Power is a prerequisite before the Generating Facility and the Interconnection Customer's Interconnection Facilities can be interconnected to the Distribution System.

## **1.2. Limitations**

The criteria and requirements of this document are applicable to all three phase Generating Facilities with a Generating Facility Capacity greater than 100 kW that are interconnected with NS Power’s radial Distribution Systems, at distribution primary voltages (rated less than 26,400 V phase to phase).

This document does not define the maximum aggregate capacity that may be accommodated by a given Distribution System circuit or feeder. The ability to connect to any Distribution System circuit or feeder may be limited by NS Power if the maximum aggregate capacity has been reached.

The requirements of this document do not apply to back-up generation systems utilizing automatic transfer schemes in which load is transferred between the generator and the Distribution System in a momentary “break-before-make” operation.

The requirements in this document are not intended to provide protection of the Interconnection Customer’s facilities. The Interconnection Customer is fully responsible for protecting their facilities in such a manner that faults or other disturbances on the Distribution System do not cause damage to their equipment.

This document is not intended or provided as a design specification or as an instruction manual for the Interconnection Customer or their agents. Persons using information included in the document do so at their own risk and at no risk to NS Power, and they rely solely upon themselves to ensure that their use of all or part of this document is appropriate in the particular circumstances.

The Interconnection Customer or their agents recognize that they are, at all times, solely responsible for design, construction, and operation of the Interconnection Customer’s facilities, unless alternative operating arrangements have been established in the SSGIA. NS Power, its servants or agents shall not be or become an agent of the Interconnection Customer in any manner howsoever arising.

The advice of NS Power, its servants or agents, that the customer-owned plant design or equipment meets certain limited requirements of NS Power does not mean, expressly or by implication, that all or any of the requirements of the law or other Good Utility Practices have been met by the Interconnection Customer in their facilities.

The use of this document does not supersede or exclude any requirements for interconnection required in the SSGIA, the document “Nova Scotia Power Rates, Regulations and Procedures”, or orders of the Nova Scotia Utility and Review Board.

All technical requirements mandated by the latest revisions of this document, Distribution System Impact Studies (DSIS), or any associated documents must be complied with. In the event of a discrepancy between documents, the DSIS shall take precedence.

## 2. Definitions

**Advanced Inverter:** A Generating Facility's Inverter that performs functions which, when activated, can autonomously contribute to Distribution System support during excursions from normal system operating voltage and frequency conditions by providing: dynamic reactive/real power support, voltage and frequency ride through, ramp rate controls, and other functions.

**Applicable Laws and Regulations:** All duly promulgated applicable federal, provincial and local laws, regulations, rules, ordinances, codes, decrees, judgments, directives, or judicial or administrative orders, permits and other duly authorized actions of any Governmental Authority.

**Cease to Energize:** The cessation of active power export from the Generating Facility and the reduction of reactive power exchange below an allowed threshold. This could be momentary (momentary cessation) or definite (trip).

**Clearing Time:** The time from the start of the abnormal condition to when the distributed energy resource Ceases to Energize the distribution system.

**CSA:** Canadian Standards Association, an accredited standards development organization within Canada.

**Double Fed Induction Generator (DFIG):** a generator in which rotor currents are controlled using a power interface to enable variable rotor speed for improved energy capture as well as extended reactive power capabilities.

**Distribution System:** NS Power's facilities nominally rated at 26,400 V or less which are used to distribute electric power between substations and customer loads.

**Distribution Generator Interconnection Procedures (DGIP):** A document which defines the procedure and requirements to be followed by the Interconnection Customer to request interconnection of a Generating Facility with a Generating Facility Capacity greater than 100kW.

**Distribution System Impact Study (DSIS):** A fee-based technical study performed by NS Power to identify impacts and limitations of interconnecting a proposed Generating Facility with the Distribution System. The DSIS typically includes technical requirements to address identified adverse effects and the associated costs for changes/upgrades required to the Distribution System to accommodate the addition of the Generating Facility.

**Generating Facility:** The Interconnection Customer's electricity production device to be interconnected with the Distribution System.

**Generating Facility Capacity:** The net capacity of the Generating Facility, or the aggregate net capacity of the Generating Facility, where it includes multiple energy production devices.

**Good Utility Practice:** Those practices, methods or acts (including but not limited to the practices, methods and acts engaged in or approved by a significant portion of the electric utility industry in North America) that at a particular time, in the exercise of reasonable judgment, would have been expected to accomplish the desired reliability, safety, environmental protection, economy and expedition as applied and practiced in the utility industry with respect to power generation, delivery, purchase and sale.

**Hertz (Hz):** A measure of the number of times or cycles that a periodic signal repeats in a second, also denoted as cycles per second.

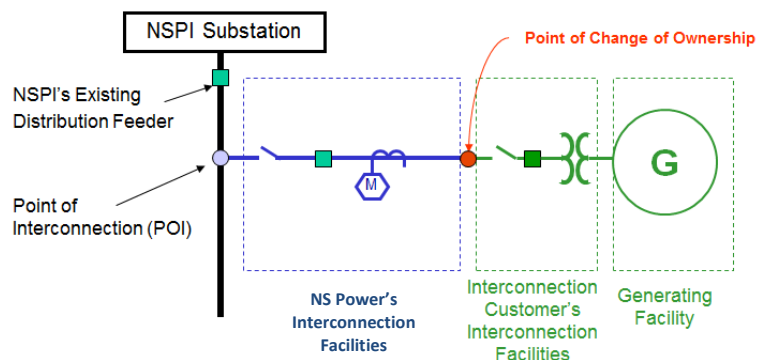
**IEEE:** The Institute of Electrical and Electronics Engineers, Inc., an organization that develops voluntary standards relating to electrical safety and product performance.

**Interconnection:** The addition of a Generating Facility to the Distribution System.

**Interconnection Customer:** The owner/operator of the Generating Facility and the Interconnection Customer's Interconnection Facilities.

**Interconnection Customer's Interconnection Facilities:** All facilities and equipment located between the Generating Facility and the Point of Change of Ownership necessary to interconnect the Generating Facility to the Distribution System.

**Interconnection Facilities:** These facilities include both the NS Power's Interconnection Facilities and the Interconnection Customer's Interconnection Facilities. Collectively, Interconnection Facilities include all facilities and equipment between the Generating Facility and the Point of Interconnection necessary to interconnect the Generating Facility to the Distribution System, as shown below for clarity.



**Inverter:** An electronic device that converts direct current (DC) to alternating current (AC). The input voltage, output voltage and frequency, and overall power handling depend on the design of the specific device or circuitry. The inverter does not produce any power; the power is provided by a DC source, such as photovoltaic panels.

**Islanding:** A condition in which an isolated portion of the Distribution System is energized solely by one (or more) Generating Facility.

**Isolation:** Physically disconnected or separated from all sources of dynamic energy by approved devices or procedures.

**Metering Equipment:** All metering equipment installed or to be installed at the Generating Facility pursuant to the Standard Small Generator Interconnection and Operating Agreement (SSGIA) at the metering point, including but not limited to instrument transformers, MWh-meters, data acquisition equipment, transducers, remote terminal unit, communications equipment, phone lines, cellular modems and fiber optics.



**NS Power's Interconnection Facilities:** All facilities and equipment owned, controlled, or operated by NS Power located between the Point of Interconnection and the Point of Change of Ownership.

**Paralleled:** A condition in which the Interconnection Customer's Generating Facility is connected to a point common with the Distribution System, with the intent to transfer power between the two systems.

**Point of Change of Ownership:** The point where the Interconnection Customer's Interconnection Facilities connect to NS Power's Interconnection Facilities.

**Point of Interconnection:** The point where the Interconnection Facilities are connected to NS Power's Distribution System.

**Smart Inverter:** See Advanced Inverter

**Stabilized:** A condition where the Distribution System has returned to stable operation within contingency voltage limits ( $110\% \geq \text{Voltage} \geq 88\%$ ) and frequency limits ( $61.2 \text{ Hz} \geq f \geq 58.8 \text{ Hz}$ ) for 5 minutes or an alternate time determined by NS Power, following a system disturbance which has resulted in a disconnection of the Generating Facility.

**Standard Protection Code:** NS Power's set of safe work practices for work on the Distribution System designed to ensure the safety of workers and security of the Distribution System.

**Standard Small Generator Interconnection Agreement (SSGIA):** A document which defines the responsibilities of the Interconnection Customer and NS Power; identifies key contacts; identifies electrical characteristics of the Interconnection Customer equipment and requirements for the safe and orderly operation and of the Interconnection Customer's facilities with the Distribution System.

### 3. Interconnection Process

All interconnecting Generating Facilities >100kW are required to follow NS Power's Distribution Generator Interconnection Procedures (DGIP). These procedures can be found on NS Power's Open Access Same-time Information System (OASIS) web site at: [www.nspower.ca/oasis/generation-interconnection-procedures](http://www.nspower.ca/oasis/generation-interconnection-procedures)

## 4. Safety Requirements

### 4.1. NS Power Safety Requirements - Standard Protection Code

Safe work procedures described in NS Power's Standard Protection Code<sup>2</sup> document will be followed when NS Power is performing any applicable work on the interconnected power system, including providing isolation and temporary grounding. Interconnection Facilities owners are responsible to follow applicable Nova Scotia Department of Labour and Advanced Education Regulations for carrying out work on their system.

### 4.2. Electrical Inspection Act<sup>3</sup> & Canadian Electrical Code Part I & II (CEC)<sup>4</sup>

The Interconnection Customer's installation must meet all applicable national, provincial and municipal electrical construction and safety codes, including, without limitation, the Electrical

Installation and Inspection Act. Except as expressly permitted by law, all electrical equipment must have CSA or equivalent approval.

Information Bulletins regarding NS Power Electrical Permits (B-B1-002), and Customer Owned High Voltage Equipment (B-36-000), along with other bulletins can be found at: <https://www.nspower.ca/your-home/building-renovating/electrical-inspections/bulletins>

### **4.3. *Permission to Operate***

Under no circumstances shall the Interconnection Customer begin parallel operation of their Generating Facility until final written approval in the form of a signed “Standard Small Generator Interconnection Agreement (SSGIA)” has been provided by NS Power.

### **4.4. *Islanded Operation***

Under no circumstances shall a Generating Facility be permitted to operate in an islanded condition (i.e., the portion of distribution line to which the generator is connected becomes isolated from the Distribution System).

## **5. *Distribution System – Characteristics & Requirements***

The Distribution System in Nova Scotia is of common North American design. These systems were designed to take power from a single source (substation connected to the transmission system) and distribute it to consumers. The design, operating and maintenance practices used by utilities for such systems are based on this single source concept.

The interconnection of parallel generation with these systems presents several technical and safety related issues that must be dealt with before permitting the Generating Facility to interconnect with the system. Some of the issues can be dealt with in the design of the Generation Facilities and the interconnection equipment. Other issues must be addressed through the establishment of the SSGIA governing the operation of the Generating Facility.

The specific technical issues and solutions are dependent on the characteristics of the Distribution System and type of generation employed.

### **5.1. *Configuration and Grounding***

NS Power's primary Distribution System is a 3-phase, 4-wire multi-grounded common neutral system (“effectively grounded-wye”) operated at three typical voltage levels:

- 4,160 Volts line to line; 2,400 Volts line to ground (4 kV)
- 12,470 Volts line to line; 7,200 Volts line to ground (12 kV)
- 24,940 Volts line to line; 14,400 Volts line to ground (25 kV)

Primary Distribution System operating at 4kV is being phased out in Nova Scotia. Any Interconnection Customer intending to connect their Generating Facility to 4kV infrastructure must also make provision for operation at 12kV or 25kV, as identified by NS Power in the DSIS.

Distribution transformers, which step the primary voltage down to utilization voltages, are mainly single-phase units with primaries connected phase to ground. Three phase distribution transformers are normally configured grounded wye to grounded wye. This generally provides a single intentional ground path for short-circuit currents (one zero-sequence path) and has been

utilized in the design of short-circuit protection applied to distribution feeder systems. NS Power's standard secondary supply voltages are:

- 120/240 Volts 1-Phase, 3-Wire
- 120/208 Volts Solidly Grounded Wye 3-Phase, 4-Wire
- 347/600 Volts Solidly Grounded Wye 3-Phase, 4-Wire

## **5.2. Voltage Standards**

NS Power maintains voltage levels at all points on the Distribution Systems in compliance with "CSA CAN-3-C235-1983 (R2015) Preferred Voltage Levels for AC Systems, 0 to 50,000 Volts, Electric Power Transmission and Distribution"<sup>5</sup>.

## **5.3. Phasing**

Phasing is not standardized across Distribution Systems. Where necessary, the phase sequence and the direction of rotation must be coordinated with the Distribution System.

## **5.4. Voltage Flicker, Dips and Unbalance**

Voltage flicker and voltage dips refer to transient or periodic variations of voltage which cause objectionable lamp flicker and/or disturbances to connected equipment. Inrush current during starting of motors or generators typically causes a voltage dip whereas voltage flicker is a quasi-continuous variation of voltage that could be caused by arc-welder, arc-furnaces or variations in the real or reactive power output of a generator.

NS Power has established guidelines for the Distribution System regarding voltage dips and voltage flicker. These are provided in Section 6.14.

Although the Distribution System is a three-phase system, loads are connected phase to ground and much of the load is supplied from single-phase laterals. As a result, the load on the three-phase system is not perfectly balanced. The unbalanced load in turn causes a degree of voltage unbalance along the distribution feeder.

Voltage unbalance is defined as the maximum deviation from average phase-to-phase voltage divided by the average phase-to-phase voltage. Unbalanced voltages may result in tripping of generators and reduced generator capabilities. During normal operation, the primary Distribution System has a phase-to-phase voltage unbalance which is normally less than 3%. In some rural locations the voltage unbalance can be higher. The Interconnection Customer should obtain an estimate from the generator manufacturer of the generator's capabilities when subjected to negative sequence voltages of 3% or more.

The addition of any Generating Facility should not increase the voltage unbalance to more than 3% at any point on the Distribution System. If the generator is unable to tolerate this inherent voltage unbalance, the Interconnection Customer may request that NS Power make system modifications to lower voltage unbalance (to the extent that is achievable by NS Power) at the Interconnection Customer's expense.

## **5.5. Voltage and Current Distortion**

NS Power has adopted "IEEE 519 – 2014 IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems"<sup>6</sup>. This establishes harmonic distortion limits for the Distribution System. It provides the harmonic voltage distortion levels that can be expected

on Distribution Systems and the current distortion limits that the Generating Facility must operate within. See section 6.15.

## **5.6. Frequency**

The power system in Nova Scotia is connected to the North American grid. As a result of this tie, the Nova Scotia system has tight frequency control which rarely varies more than 0.2 Hz from its 60 Hz nominal value.

On occasion, Nova Scotia (with or without New Brunswick) may become separated from this system and operate independently as an electrical island. The islanded condition may be very brief in duration or may last several weeks as maintenance to lines and substations is carried out. When NS Power's systems operate in an islanded state, the frequency may vary from 59.5 to 60.5 Hertz (Hz) during normal (uneventful) operation. Consequently, NS Power may require that distribution-connected generators disconnect from the Distribution System if NS Power is operating in an islanded condition.

There are also conditions that may result in relatively brief frequency excursions from 57Hz to 61Hz.

## **5.7. Fault Levels, Fault Clearing and Restoration**

The maximum design fault level of the 12.5 kV system is 9,000 A. The maximum design fault level of the 25 kV system is 8,000 A. Actual fault levels will vary from substation to substation and will decrease with distance from the substation.

Short-circuits on distribution feeders are detected and cleared by the operation of protective devices such as reclosers and circuit breakers. These protective devices detect and interrupt the fault current and then reclose the circuit to restore service. If the short circuit remains (permanent fault) then the protective device again interrupts the circuit and again recloses. Reclosing is a common utility practice. This cycle may be repeated multiple times before the protective device opens and must be manually reclosed.

Reclosing can pose a risk to synchronous generators. If the feeder is reclosed with the generator still connected and operating out of phase with the system (i.e. islanded operation), the machine can be subjected to high torque.

Short-circuit clearing times (fault initiation to interruption) typical of the Distribution System are less than 1.0 second but can be longer in some instances.

Single phase "Type T" cutout fuses are also utilized on the Distribution System to operate under downline fault conditions. Fuses are sized to coordinate with feeder recloser protection.

## **5.8. Reliability**

The Distribution System feeder circuits typically experience several outages per year due to exposure to human and natural factors. These outages may be brief or may extend over many hours. In addition to these forced outages, planned maintenance of the Distribution System may require that supply feeders be removed from service for periods of time.

## **5.9. Resonance and Self-Excitation**

The interconnection of generating facilities to the Distribution System can lead to resonant voltage conditions on the Distribution System. Resonance can occur as a result of the interaction between the connected Generating Facilities and capacitor banks located on the Distribution System and/or near the terminals of the generator. There are several conditions that may result in resonance, such as self-excitation of the generator or resonant grounds. Harmonic resonance can also occur in both normal operation and if islanding occurs.

If these conditions occur, damage to the Interconnection Customer's equipment and/or primary connected equipment may result.

NS Power requires under and over frequency, and over and under voltage protection at the Interconnection Customer's Generation facilities to address this situation.

## **5.10. Generator Types**

### **5.10.1. Synchronous Generators**

Synchronous generators are generally capable of contributing current for faults occurring on the Distribution System. Synchronous generators require synchronizing equipment to ensure proper synchronizing of the generator equipment to the Distribution System.

NS Power utilizes automatic reclosing as part of its Distribution System protection scheme. This reclosing function must be considered in the design of a synchronous Generating Facility's protection scheme to avoid damage to the generator due to high torques that could result during non-synchronized paralleling.

Following the disconnection of the generator from the Distribution System due to a protection operation, sufficient time must be allowed to ensure the Distribution System has Stabilized prior to reconnection of the generator.

### **5.10.2. Power Electronic Converter (Inverter) Systems**

Inverters convert direct current (DC) power to alternating current (AC) power by means of electronic switching devices. Switching can be controlled by the AC voltage waveform of the NS Power supply system (grid-dependent) or by internal electronic circuitry (grid-independent). Inverters are generally not capable of supplying sustained fault current. Grid-independent inverters are capable of supplying load current independently of the NS Power supply system.

Advanced (Smart) Inverters have the capability to provide a range of grid-support functions. All inverter-based Generating Facilities having a valid interconnection request on or after the effective date of this document shall comply with the Advanced Inverter Requirements set forth in Section 6.17 of this document.

### **5.10.3. Induction Generators**

Induction generators are basically induction motors that are mechanically driven above synchronous speed to produce electric power. Reactive power supply for induction generators may pose design problems depending on the generator size. Special considerations for induction generators are:

- Capacitors may be necessary to limit the adverse effects of reactive power flow on NS Power's system voltage regulation.
- Self-excitation of the induction generator due to installed capacitors can produce abnormal high magnitude, distorted voltages.
- Voltage flicker resulting from induction generators starting, particularly on remote portions of the Distribution Systems may be unacceptable to NS Power.

## **6. Interconnection Customer's Generating and Interconnection Facilities – Requirements**

This section addresses the technical requirements for the interconnection of generation with the Distribution System.

All Inverter-based Generating Facilities with a valid interconnection request on or after the effective date of this document shall comply with the Advanced Inverter Requirements set forth in Section 6.17 of this document.

In general, the Generating Facility and its associated Interconnection Facilities shall be designed and equipped to:

- Prevent the Generating Facility from remaining connected to the Distribution System upon loss of the supply to the Distribution System (anti-islanding);
- Ensure that any Interconnection Customer's facilities remain effectively grounded at all locations, in all sustained, temporary, and transient conditions.
- Prevent sustained voltage regeneration caused by the Interconnection Facility step up transformers and/or grounding transformers during loss of one phase of the Distribution System supply.
- Prevent connection or parallel operation of the Generating Facility with the Distribution System unless the Distribution System voltage and frequency are of normal magnitude; and,
- Detect and promptly disconnect from the Distribution System for over-current fault conditions. Interrupt the maximum available fault current at the point of connection with the Distribution System.

Interconnection Facilities must remain effectively grounded at all times, including when disconnected from the Distribution System in accordance with Section 6.3 of this document.

### **6.1. Adverse Effects on Other Customers**

The Generating Facility must not adversely affect the Distribution System or service to any other connected customers or facilities. To limit the potential for adverse effects on other customers, NS Power requires that Generating Facilities greater than 100kW interconnect with the Distribution System via dedicated step-up transformers unless otherwise agreed to by NS Power.

## 6.2. Isolating Device

A manual disconnecting device between the Generating Facility and the Distribution System with a visible break for isolation purposes must be provided. The form of this device will vary with the service voltage and capacity but in all cases must be:

- accessible to NS Power,
- capable of providing a visible break, breaking load, opening all phases simultaneously (Gang-operated), and,
- capable of being locked in the open position.

The location and form of the device must be approved by NS Power. This isolating device is owned by the Interconnection Customer and is therefore subject to the requirements of the Canadian Electrical Code - specifically (but not limited to) Sections 36-204, 36-214, 64-406, 84-024. Additional disconnection devices may be required for Generating Facilities with more than one generator.

## 6.3. Grounding Requirements

Following the addition of any Interconnection Customer Interconnection Facilities and a Generating Facility to the Distribution System, the system must remain effectively grounded at all locations, in all sustained, temporary, and transient conditions. Operating temporarily ungrounded at any time is not permitted due to the risk of overstressing surge arrestors.

To minimize desensitization of NS Power’s ground fault protection, the Interconnection Customer facilities must be effectively grounded. To be considered effectively grounded by NS Power, the grounding of the Interconnection facilities, as seen from the Generating Facility high voltage terminals with the NS Power system disconnected and the generator on-line, shall be such that:

$$2.5 < X_0/X_1 < 3.5^a \text{ and } R_0/X_1 < 0.7$$

**OR**

$$X_0/X_1 > 2.5 \text{ and the TOV} < 130\%$$

**Where:**

**X<sub>0</sub> = zero sequence reactance**

**X<sub>1</sub> = positive sequence reactance**

**R<sub>0</sub> = zero sequence resistance**

**TOV = Temporary Over-voltages**

The transient reactance of the Generating Facility, including all apparatus that may be connected to the high voltage (HV) and low voltage (LV) systems, must be used for all conditions. To achieve this requirement, neutral grounding reactors may have to be installed on transformers with grounded-wye (Wye-gnd) HV windings or through grounding facilities added to the HV or LV system.

The required values can be achieved by one or more of the following methods:

- a. selecting the impedance of a grounding transformer;
- b. installation of a neutral grounding reactor on the neutral of a step up transformer; or
- c. grounding the generator through a neutral reactor.

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<sup>a</sup> where these values can be verified by calculations and test reports provided by the Interconnection Customer.

The choice of the method used by the Interconnection Customer will depend on the configuration and specifications of the Generating Facility and is subject to review and acceptance by NS Power.

The Interconnection Customer’s grounding facilities must be able to withstand the continuous zero-sequence currents resulting from normal levels of steady state and transient phase current unbalance occurring in the Distribution System.

High voltage grounding transformer banks must be able to withstand faults on the NS Power Distribution System without being disconnected or compromised. Grounding banks are not to be designed with fuse protection.

#### **6.4. Interconnection Transformer Configuration**

The Generating Facility Interconnection Transformer shall not cause voltage disturbances or disrupt co-ordination of Distribution System ground fault protection.

For all three phase interconnections utilizing a single three phase transformer, NS Power requires a Wye-gnd:Wye-gnd winding configuration, 4/5-leg transformer with grounding provided by either the generator or by means of a Low Voltage (LV) grounding transformer (as shown in Table A1 of Appendix A). In this configuration, the connection of a LV grounding transformer is to be electrically located such that when the generator is disconnected, the LV grounding transformer is also disconnected from the Distribution System.

Other configurations may be permitted provided the Interconnection Customer can demonstrate that all grounding and protection requirements are met. As part of the Interconnection Application assessment process, Interconnection Customers must identify their proposed transformer connection for review and acceptance by NS Power and are strongly advised to do so in advance of the transformer and major equipment purchase.

NS Power recommends that interconnection transformers have off-load taps on the primary side with a range of 2 x 2.5% above and below nominal voltage. For any interconnection where the Generating Facility is not served by the same transformer serving the customer load, the interconnection transformer must have off-load taps.

#### **6.5. Synchronizing Facilities**

Synchronous generators and self-commutated inverters connected to the Distribution System must be equipped with synchronizing facilities to permit connection only when both the frequency and voltage are within the limits shown in Table 1. The settings must be submitted to NS Power for approval prior to finalizing the SSGIA. The Interconnection Customer is responsible for synchronizing the generators to the Distribution System and ensuring that these synchronizing facilities are in good working order at all times.

Aggregate Ratings of Generation (kVA)	Frequency Difference ( $\Delta$ Hz)	Voltage Difference ( $\Delta$ V, %)	Phase Angle Difference (degrees)
0 to 500	0.3	10	20
>500 to 1,500	0.2	5	15
>1,500	0.1	3	10



**Table 1: Synchronization Limits – from IEEE 1547-2018 – Table 5<sup>7</sup>**

All Generating Facilities must have protection employed which prevents any generator from being started, and synchronizing attempted, until the Distribution System feeder has voltages and frequencies that have Stabilized within normal range for a period of time, as measured at the Point of Interconnection. The delay period must be settable in the range of 5-60 minutes. The actual setting will be specified by NS Power and indicated in the DSIS and/or the SSGIA.

## 6.6. Voltage Regulation and Power Factor Control

Synchronous generators interconnected to the Distribution System must be equipped with excitation controllers capable of controlling voltage. The controller’s voltage set-point shall be adjustable throughout the range of 95-105% of rated terminal voltage. The actual setting will be specified by NS Power and indicated in the DSIS and/or the SSGIA. Other generator types will be required to have voltage control capabilities consistent with the above.

Induction generators must provide reactive compensation to correct their power factor to 98% measured at the output terminals of the generator unless other terms are determined by NS Power, as established in the DSIS and/or the SSGIA.

DFIG and Inverter-based wind-powered generators interconnected to the Distribution System must be capable of controlling voltage. The controller’s voltage set-point shall be adjustable throughout the range of 95-105% of rated terminal voltage. The actual setting will be specified by NS Power and indicated in the DSIS and/or the SSGIA. The generator must have the capability of operating with a range of 95% lagging to 95% leading power factor when generating its real power rated capability.

All other generators must have the capability of operating with a range of 95% lagging to 95% leading power factor when generating its real power rated capability.

Refer to Section 6.17 for additional voltage regulation and power factor control requirements specific to the interconnection of smart/advanced inverter-based generation.

## 6.7. Off-Nominal Frequency Operation

In conformance with the NPCC Regional Reliability Reference Directory #12 “Under Frequency Load Shedding Program Requirements, July 9, 2013 (Figure #1)”<sup>8</sup>; NERC Standard “PRC 024-2 Generator Frequency and Voltage Protective Relay Settings Version 1 (Attachment 1 – Off Nominal Frequency Capability Curve)”<sup>9</sup>, IEEE 1547-2018 “IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems (Table 18)”<sup>7</sup>, and CSA C22.3 No.9:20 “Interconnection of distributed resources and electricity supply systems (Table 9)”<sup>10</sup> the settings in Table 2 are required for generator over and under frequency tripping:

Function	Frequency (Hz)	Clearing Time
OF2	>62	0.16 sec
OF1	>61.2	300 sec
UF1	<58.5	300 sec
UF2	<56.5	0.16 sec

**Table 2: Required Over and Under Frequency Tripping Settings**

Table 3 defines the frequency ranges and the required frequency ride through performance for Advanced Inverters. Generating Facilities shall Cease to Energize the Distribution System within the prescribed trip time whenever the frequency at the Point of Interconnection deviates from the allowable frequency operating range. Unless provided alternate settings by NS Power all Generating Facilities must comply with the standard frequency ride-through and trip settings specified in Table 2 and, if Advanced Inverter-based, Table 3.

Whenever the Distribution System frequency at the Point of Interconnection is outside Nominal Operation Range for the parameters set forth in Table 3, the Advanced Inverter Generating Facility's protective functions shall cause the Generating Facility to Cease to Energize the NS Power's Distribution System, as follows:

- a) The Generating Facility shall stay connected to the Distribution System while the system remains within the "Ride-Through Duration" frequency-time range and must function in the corresponding "Operating Mode" for each Frequency Condition listed in Table 3.
- b) In the OF1 region, the Generating Facility shall have the capability to reduce power output as a function of frequency (per Section 6.17.3. Frequency-Watt Mode). The activation state and settings of this mode will be determined by NS Power in the DSIS and/or the SSGIA.
- c) If the Distribution System frequency recovers to a normal range before to the expiration of the Ride-Through time, the Generating Facility shall restore continuous operation within 2 seconds.
- d) If the Distribution System frequency does not exit the ride-through region and returns from either Level 2 (Over/Under) region to the corresponding Level 1 (Over/Under) region, the Generating Facility shall restore available current within 2 seconds.
- e) Post Ride-Through Start/Restart Conditions: Before restarting Generating Facility output after a ride through event, the system frequency shall be Stabilized (i.e. a system frequency between 61.2 Hz and 58.8 Hz for 5 minutes or another time as established by NS Power). When the system frequency is in range of 61.2 Hz and 58.8 Hz, the Generating Facility can operate according to its available power output and is not required to increase or decrease power as a function of system frequency.
- f) Different settings than specified and operating modes than those in Table 3 may be specified by NS Power in the DSIS and/or the SSGIA.

Frequency Condition	Distribution System Frequency	Ride-Through Duration (sec)	Inverter Operating Mode <sup>1, 2</sup>	Clearing Time: adjustable up to and including (sec) <sup>2</sup>
Level 2 Over Frequency (OF2)	$f > 62$	No Ride Through	Cease to Energize	0.16
Level 1 Over Frequency (OF1)	$62 \geq f > 61.2$	299	Mandatory Operation	300
Normal Frequency Range	$61.2 \geq f \geq 58.8$	Normal Range	Continuous Operation	Not Applicable
Level 1 Under Frequency (UF1)	$58.8 > f \geq 57$	299	Mandatory Operation	300
Level 2 Under Frequency (UF2)	$f < 57$	No Ride Through	Cease to Energize	0.16

**Table 3: Generating Facility Frequency Ride-Through Function Settings from (Table 14) CSA C22.3<sup>10</sup>**

**Table 3 Notes:**

- Operating Modes:  
Mandatory Operation: the generator continues to output power during the Ride-Through Duration time and then starts the shutdown process.  
Cease to Energize: the generator ceases to provide active power and reduces reactive power exchange below an allowed value.  
“Continuous Operation”: the generator continues to output power as available.
- Actual settings will be specified by NS Power and indicated in the DSIS and/or the SSGIA.

### 6.8. Off-Nominal Voltage Operation

The Generating Facility shall have protective devices installed to detect abnormal voltages and to disconnect the generator from the system.

The equipment and protective settings required to accomplish this will depend on the type of generation, the configuration of the step-up transformer and the specifics of the interconnected system. In general, this will require detection of the fundamental frequency voltage on three individual phases (in some cases phase-to-phase voltages). The voltage sensing equipment may be installed at the Point of Interconnection or on the low-voltage terminals of the step-up transformer.

The Generating Facility Over/Under voltage protection will be set, unless otherwise specified by NS Power, as shown in Table 4.

Function	Voltage (% of nominal voltage)	Clearing Time
OV2	>120	0.16 sec
OV1	>110	2 sec
UV1	<88	10 sec
UV2	<45	0.16 sec

**Table 4: Voltage Limit Default Settings – from (Table 10) CSA C22.3 No.9<sup>10</sup>**

Table 5 defines the voltage ranges and the required voltage ride through performance for Advanced Inverters. Generating Facilities shall Cease to Energize the Distribution System within the prescribed trip time whenever the voltage at the Point of Interconnection deviates from the allowable voltage operating range. Unless provided alternate settings by NS Power, Generating Facilities must comply with the standard voltage ride-through and trip settings specified in Table 4 and, if Advanced Inverter-based, Table 5.

Whenever the Distribution System voltage at the Point of Interconnection is outside Normal Voltage Range for the parameters set forth in Table 5, the Advanced Inverter Generating Facility's protective functions shall cause the Generating Facility to Cease to Energize the Distribution System, as follows:

- a) The Generating Facility shall stay connected to the Distribution System while the system remains within the "Ride-Through Duration" voltage-time range and must function in the corresponding "Operating Mode" for each Voltage Condition listed in Table 5.
- b) In the Normal Voltage – High (NVH) region, the Generating Facility may be required to reduce power output as a function of voltage (per Section 6.17.2. Volt-Watt Mode). The activation state and settings of this mode will be determined by NS Power in the DSIS.
- c) If the Distribution System voltage recovers to normal prior to the expiration of the Ride-Through time, the generator shall restore continuous operation within 2 seconds.
- d) If the Distribution System voltage does not exit the ride-through region and returns from the Under Voltage UV3 region to the UV2 or UV1 region, the Generating Facility shall restore available current within 2 seconds.
- e) Post Ride-Through Start/Restart Conditions: Before restarting the Generating Facility output after a ride through event, the system voltage shall be Stabilized (i.e. between 110% to 88% of nominal system voltage for 5 minutes or another time as established by NS Power in the DSIS and/or the SSGIA).
- f) Different settings than specified and operating modes than those in Table 5 may be specified by NS Power in the DSIS and/or the SSGIA.

Voltage Condition	Voltage at POI (% of Nominal)	Ride-Through Duration Default Setting (Sec)	Inverter Operating Mode <sup>1, 2</sup>	Clearing Time: Adjustable up to and including (sec)	Post Ride-Through Start/Restart Conditions	
					Voltage Criteria (V) (% of Nominal)	Time Delay (min) <sup>2</sup>
Level 2 Over Voltage (OV2)	$V \geq 120\%$	No Ride Through	Cease to Energize	0.16	$110\% \geq V \geq 88\%$	5 - 60
Level 1 Over Voltage (OV1)	$110\% < V < 120\%$	1	Mandatory Operation	12	$110\% \geq V \geq 88\%$	5 - 60
Normal Voltage Range - High (NVH)	$100\% < V \leq 110\%$	Indefinite	Continuous Operation	Not Applicable Within Normal Voltage Range		
Normal Voltage Range - Low (NVL)	$88\% \leq V < 100\%$	Indefinite	Continuous Operation			
Level 1 Under Voltage (UV1)	$50\% \leq V < 88\%$	10	Mandatory Operation	20	$110\% \geq V \geq 88\%$	5 - 60
Level 2 Under Voltage (UV2)	$V < 50\%$	No Ride Through	Cease to Energize	0.16	$110\% \geq V \geq 88\%$	5 - 60

**Table 5: Generating Facility Voltage Ride-Through Function Settings**

**Table 5 Notes:**

- Operating Modes:  
Mandatory Operation: the generator continues to output power during the Ride-Through Duration time and then starts the shutdown process.  
Cease to Energize: the generator ceases to provide active power and reduces reactive power exchange below an allowed value.  
Continuous Operation: the generator continues to output power as available.
- Actual settings will be specified by NS Power and indicated in the DSIS and/or the SSGIA.

## 6.9. Islanding

Islanding is not permitted, i.e. a Generating Facility shall not energize the Distribution System when the Distribution System is de-energized. The Generating Facility shall not remain energized after the portion of the Distribution System to which it is connected has become electrically separated from the rest of the Distribution System. For inverter based generators, within 2 seconds of island formation, the islanding condition must be detected and the Generating Facility must Cease to Energize the Distribution System.

Unintentional islanding can result in poor power quality, unsafe work environments, equipment damage and a lack of adequate short-circuit protection. For these units every effort must be made to ensure that islanding conditions are detected and the generator isolated from the system.

Specialized protection devices or schemes using communication channels between the NS Power supply point and the generator (transfer trip) are required to ensure that islanding does not occur when generators are capable of doing so.

For interconnected synchronous and self-commutating inverter generation less than or equal to 1 MW where the generator has anti-islanding protection, NS Power will permit the installation of an NS Power recloser (owned by NS Power, paid by Interconnection Customer) complete with Over/Under Frequency, Under/Over Voltage, Overcurrent, Voltage Restrained Overcurrent, and Phase Unbalance protections as an alternative to installing a transfer trip from the substation recloser (and from any downline reclosers between the substation and Generating Facility) to

the Generating Facility main breaker. This applies where the aggregate nameplate capacity of existing, committed<sup>b</sup> and the proposed Generating Facility is less than 50% of:

- a. the minimum feeder load of the feeder supplying the Generating Facility,
- b. the minimum feeder section load of the feeder section supplying the Generating Facility (i.e., downstream recloser supplying Generation Facility),
- c. the minimum feeder load of the feeder supplying the Generating Facility and of any downstream section of the feeder supplying the existing, committed and the proposed Generating Facilities.

It should be noted that generator operation will not be permitted at Generating Facilities utilizing a transfer trip when protection devices from which the transfer trip is being sent, are out of service.

### **6.10. Thermal Limits and Overcurrent Protection**

Thermal limits of NS Power equipment shall not be exceeded as the result of the addition of the Generating Facility.

Protection shall be provided to detect and cease energization for all phase to phase and phase to ground faults on the Distribution System.

### **6.11. Protection of Equipment & Fault Detection**

The proper detection and isolation of all types of faults, whether they occur on the Distribution System, or within the Interconnection Customer's facilities, is essential to ensure safe operation and limit damage to equipment.

The Interconnection Customer must ensure that their protection devices detect abnormal system conditions and isolate their facilities from the Distribution System, including but not limited to: over and under frequency (per Section 6.7), over and under voltage (per Section 6.8) and anti-islanding (per Section 6.9).

NS Power will normally have Distribution System protection at the Point of Interconnection in the form of a distribution class recloser equipped with an electronic recloser controller, as specified and supplied by NS Power at the Interconnection Customer's cost. This device is intended to protect NS Power's system from adverse conditions at the interconnection site. This device is not intended to protect the Interconnection Customer's equipment. The settings for the recloser protective functions will be established by NS Power on a site-specific basis and typically include phase and ground trips, over and under voltage protection, and over and under frequency protection. Other protection may be required dependent on the facility.

The following protection functions may also be available or required:

- Reclose Blocking to ensure that the generator is not on-line when the Distribution System auto-recloses (re-energizes circuit automatically following a fault detection)
- Use of transfer-tripping to ensure that the generator disconnects whenever the supply distribution circuit recloser or downline device between the supply recloser and the Generating Facility has tripped open.

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<sup>b</sup> Committed generation refers to generation projects which are queued higher in the Advanced Distribution Interconnection Queue, on the same feeder/section as the proposed Generating Facility.

## **6.12. Automatic Start/Restart of Generation Facilities**

Individual generators are typically permitted to automatically start or restart after tripping from the Distribution System. This automatic restart may occur only after the Distribution System voltages and frequencies have Stabilized and the 5-60 minute delay has expired. This time delay is necessary to preclude islanding, reduce stress on the generators resulting from repetitive faults and to stagger the starting of units following a fault or disturbance.

NS Power will specify the time delay to be applied to the individual generators in the DSIS and/or the SSGIA.

## **6.13. Protection Coordination**

The protection systems installed by the Interconnection Customer shall coordinate with NS Power's protection facilities. The Interconnection Customer shall submit details of the protection facilities and proposed settings to NS Power for review and acceptance prior to finalization of the SSGIA. Any revisions to settings must also be submitted to NS Power for review and acceptance in accordance with the terms of the SSGIA.

## **6.14. Voltage Variations**

### **6.14.1. Voltage Flicker**

The Interconnection Customer is to ensure that the operation of the Generating Facility does not cause voltage variations on the Distribution System that result in objectionable lamp flicker to other connected customers.

The voltage variations will be measured at the Point of Interconnection (POI). These variations can be caused by the start-up and shut-down sequences of the generator (capacitor switching, inrush, resistor by-pass etc.), referred to as "voltage dips", or may be caused by the quasi-continuous variation of the prime mover (e.g. wind) which is referred to as "flicker".

The acceptable limits of flicker emissions from any Generation Facility on NS Power's Distribution System, measured at the designated Point of interconnection in accordance with the IEEE 1547-2018 (Table 25) are:

$$P_{st95\%} \leq 0.35$$

$$P_{lt95\%} \leq 0.25$$

**Where  $P_{st}$  is the emission limit for the short-term flicker severity and  $P_{lt}$  is the long-term flicker severity.**

In computing the flicker emission levels, only periods in which the Generating Facility is in operation shall be included. These limits apply to all consecutive periods.

### **6.14.2. Voltage Dips**

The acceptable limits for voltage deviation are listed in Table 6 below. Operation of the Generating Facility from full generation to no generation, or from no generation to full generation shall cause no more than a 2.5% step change in system voltage measured at the Point of Interconnection. Similarly, disconnection of the generator at full output shall cause no more than a 2.5% step change in system voltage measured at the Point of Interconnection.

$\Delta V$ (%)	Occurrences
2.5%	$\leq 1$ time / hour
2.0%	$\leq 5$ times / hour
1.0%	$\leq 50$ times / hour
0.5%	$\leq 500$ times / hour
Dynamic voltage changes must be $\leq 2.5\%$	

**Table 6: Rapid Voltage Changes Limits**

### 6.15. Voltage & Current Distortion

The harmonic current injection from the Generating facility to the Distribution System measured at the Point of Interconnection shall not cause the limits established by IEEE 519-2014<sup>6</sup> to be exceeded. These limits are listed below in Table 7.

Maximum Harmonic Distortion in percent of $I_L$						
$I_{sc}/I_L$	Individual Harmonic Order (odd harmonics) <sup>a, b</sup>					Total Demand Distortion (TDD) <sup>c</sup>
	$3 \leq h < 11$	$11 \leq h < 17$	$17 \leq h < 23$	$23 \leq h < 35$	$35 \leq h < 50$	
$< 20^c$	4.0	2.0	1.5	0.6	0.3	5.0
20 < 50	7.0	3.5	2.5	1.0	0.5	8.0
50 < 100	10.0	4.5	4.0	1.5	0.7	12.0
100 < 1000	12.0	5.5	5.0	2.0	1.0	15.0
>1000	15.0	7.0	6.0	2.5	1.4	20.0

**Table 7: Current Distortion Limits – from IEEE 519-2014**

**Table 7 Notes:**

<sup>a</sup> Even harmonics are limited to 25% of the odd harmonic limits shown

<sup>b</sup> Current distortions that result in a DC offset, eg. Half-wave rectifiers are not allowed

<sup>c</sup> All power generation equipment is limited to these values of current distortion, regardless of actual  $I_{sc}/I_L$  where

$I_{sc}$  = maximum short circuit current at PCC

$I_L$  = maximum demand load current (fundamental frequency component) at the PCC under normal load operating conditions

The Generating Facility must be tolerant of harmonic voltage distortion levels that are indicated in IEEE 519-2014 for Distribution Systems. These distortion levels may be present in the absence of any harmonics generated by the Interconnecting Customer’s facility. These limits are listed below in Table 8.

Bus Voltage V at PCC	Individual Harmonic (%)	Total Harmonic Distortion THD (%)
$V \leq 1.0$ kV	5.0	8.0
$1$ kV < $V \leq 69$ kV	3.0	5.0

**Table 8: Voltage Distortion Limits – from IEEE 519-2014**



## **6.16. Voltage Regeneration**

Sustained voltage regeneration from the Interconnection Customer's Interconnection Facilities following the loss of a supply phase on the Distribution System is not permitted. Regenerated voltages may not be well regulated and can be well below or well above acceptable levels or may be present at or near nominal voltage. Short-circuit protection on the regenerated phase may be inadequate. The Interconnection Customer shall identify the capability of their site to regenerate voltages and shall mitigate the risk of occurrence of in the design of their facilities.

All generator step-up transformer core and winding configurations are capable of regenerating voltage, to some extent, for a lost Distribution System supply phase. Only some configurations are capable of reproducing the phase voltage at or near a nominal level. The Generating Facility's interconnection protection must be capable of detecting the loss of any phase to which the Generating Facility is connected.

Over/under high-side voltage protection alone is not an acceptable solution to protect against the regenerated phase conditions in the case where the interconnection configuration is capable of reproducing nominal or near nominal voltage. In such situations, detection of phase regeneration is possible with protection which measures zero-sequence current and voltage and negative sequence current (phase unbalance) on the high voltage (HV) and low voltage (LV) systems. The protection requirements are set out in Appendix A - Table A1.

In general, zero-sequence quantities should be used for relaying at the HV terminals and included on the LV system if grounding facilities are provided at that voltage (grounding bank or neutral grounding of generators). Negative sequence current should also be used at the HV bus and at the generator terminals.

Unless system grounding is provided in the LV system, the negative sequence current at the generator terminals will be the best means of detection of the condition. In the absence of load on the regenerated phase, as the generator loads, the negative sequence current will become significant at the generator terminals. The best protective relay measured quantities will depend on the step-up transformer configuration and how system grounding is achieved. See Appendix A Table A1 – "Open Phase Protection Requirements" for additional protection details.

To protect against the regenerated voltage in all situations, disconnection of the Interconnection Customer's Generation Facility (at the High Voltage terminals of the step-up transformer) when the generator is not running may be necessary.

It should also be considered that facilities utilized to achieve effective grounding as per the requirements of Section 6.3 could be capable of voltage re-generation. In this case, the grounding facilities would be subject to the same protection and disconnection requirements as the step-up transformer.

NS Power may request a demonstration of these protection and disconnection facilities. NS Power may also request engineering analysis of the Interconnection Customer's facilities design that demonstrates how voltage regeneration protection is provided for loss of a distribution phase on the Distribution System supply-side.

### 6.17. Advanced Inverter Functions and Operating Requirements

All Advanced Inverter-based Generating Facilities with a valid interconnection request on or after the effective date of this document shall comply with the Advanced Inverter Functions and Operating Requirements specified in Section 6.17.

All such inverter equipment shall be CSA certified and meet the functional requirements of CSA C22.3 No. 9:20 “Interconnection of distributed energy resources and electricity supply systems”.

#### 6.17.1. Advanced Inverter Protection Functions

- (a) Over and under frequency trip functions which i) cause the inverter to Cease to Energize the Distribution System whenever the Distribution System frequency at the Point of Interconnection deviates from the nominal 60 Hz frequency and timeframes set out in Section 6.7 and ii) prevent the Advanced Inverter from restarting and re-energizing the Distribution System unless the frequency has Stabilized;
- (b) Over and under voltage trip functions which i) cause the inverter to Cease to Energize the Distribution System whenever the Distribution System voltage at the Point of Interconnection deviates from the normal voltage limits and timeframes set out in Section 6.8 and ii) prevent the Advanced Inverter from restarting and re-energizing the Distribution System unless the system voltage has Stabilized; and
- (c) Anti-Islanding protection to prevent the inverter from being connected to any portion of the Distribution System that is not energized by the utility supply, in accordance with Section 6.9.

#### 6.17.2. Volt-Watt Mode

The Advanced Inverter shall be capable of altering its actual real power output when the system voltage at the Point of Interconnection exceeds the defined “volt-watt start set point (%V<sub>nom</sub>)”. The real power output of the inverter shall be reduced according to the “gradient setting (%P<sub>nom</sub>/ %V<sub>nom</sub>)”.

V-W Setting Parameter	Default setting	Range
Start Voltage (% of V <sub>nom</sub> )	106	105 to 120
Gradient (%P <sub>nom</sub> / %V <sub>nom</sub> )	0 (Disabled)	0 to 100%

**Table 9: Volt-Watt Default Settings**

**Table 9 Notes:**

- a) When the system voltage reaches or exceeds 106% of nominal, the active power output produced by the Advanced Inverter shall be reduced by X% of real power nameplate rating per %V<sub>nom</sub>.
- b) The voltage default dead-band shall be +10%/+6% (132 V to 127 V).
- c) To enable this function, Start Voltage and Gradient Settings are to be provided by NS Power in the DSIS and/or the SSGIA.

#### 6.17.3. Frequency-Watt Mode

The Advanced Inverter shall be capable of altering its actual real power output whenever the system frequency at the Point of Interconnection exceeds the defined “frequency-watt start set point (Hz)”. The real power output of the inverter shall be reduced according to the “gradient setting (%P<sub>nom</sub>/Hz)”.

f-W Setting Parameter	Default setting	Range
Start Frequency (Hz)	60.7	60.1 to 65
Gradient (%Pnom/Hz)	0 (Disabled)	0 to 100%

**Table 10: Frequency-Watt Default Settings**

**Table 10 Notes:**

- When the system frequency exceeds 60.7 Hz, the active power output produced by the Advanced Inverter shall be reduced by X% of real power nameplate rating per hertz.
- To enable this function, Start Frequency and Gradient Settings are to be provided by NS Power in the DSIS and/or the SSGIA.
- The frequency default dead-band shall be +0.7/-1.0 Hz (60.7 Hz to 59 Hz). When the system frequency is in range of 60.7 Hz and 59 Hz, the Advanced Inverter can operate according to its available power output and is not required to increase or decrease power as a function of system frequency.

#### **6.17.4. Power Factor Control**

Advanced inverters must be capable of controlling voltage and operating at a fixed, preset power factor. The controller's voltage set-point shall be adjustable throughout the range of 95-105% of rated terminal voltage. The generator must have the capability of operating with a range of 95% lagging to 95% leading power factor when generating its real power rated capability. The actual settings will be specified by NSPI and indicated in the DSIS and/or the SSGIA.

#### **6.17.5. Dynamic Volt/VAr Operations**

Advanced Inverters shall be capable of providing dynamic reactive power compensation (dynamic Volt/VAr operation) within the following constraints:

- The Advanced Inverter shall be able to consume reactive power in response to an increase in line voltage and produce reactive power in response to a decrease in line voltage.
- The reactive power provided shall be based on available reactive power, but the maximum reactive power provided to the system shall be as directed by NS Power.
- This Volt/VAr capability shall be able to be activated or deactivated in accordance with NS Power requirements, as set out in the DSIS and/or the SSGIA.
- To enable this function, the voltage thresholds and reactive power set points and %VAr/%Volt gradients are to be provided by NS Power in the DSIS and/or the SSGIA.

#### **6.17.6. Ramp Rate Requirements**

The Advanced Inverter shall have the following ramp capabilities. Ramp rates are reliant on sufficient energy being available from the Advanced Inverter.

- Continuous Operation ramp rate: For power output level changes during normal operation. The default value is 100% of maximum rated current output per second with a range of adjustment from 1% to 100%, with specific setting as provided by NS Power in the DSIS and/or the SSGIA.
- Connect/Reconnect ramp rate: Upon starting to inject power on start up or a disconnection, the inverter shall be able to control its rate of increase of power from 1 to 100% maximum current per second. The default value is 2% of maximum current output per second with specific settings as provided by NS Power in the DSIS and/or the SSGIA.

### 6.17.7. *Summary of Advanced Inverter Functions*

Default Advanced Inverter Functions	Default Activation State
a) Anti-Islanding	Activated
b) Voltage Ride Through	Activated
c) Frequency Ride Through	Activated
d) Volt-Watt Mode	Per DSIS and/or the SSGIA
e) Frequency-Watt Mode	Per DSIS and/or the SSGIA
f) Fixed Power Factor	Per DSIS and/or the SSGIA
g) Dynamic Volt-VAr Mode	Per DSIS and/or the SSGIA
h) Ramp Rates – Normal Operation	Activated
i) Ramp Rate – Reconnect Operation	Activated

## 6.18. *Interface Control and Communication Requirements*

### 6.18.1. *Interface Communications*

All Inverter Based Generation Facilities shall be equipped with information exchange capability capable of monitoring connection status, real power output, reactive power output, power factor, voltage, current, frequency, and time. Information exchange requirements shall comply with CSA Std. C22.3 (Table D.1) unless otherwise specified by NS Power. The type of acceptable protocols shall be one of the two options as per the following:

Protocol	Transport	Physical layer
DNP3	N/A	RS-232
DNP3	TCP/IP	Ethernet

All other generation facilities less than 5MW shall be equipped with ‘near real time’ telecommunications to NS Power’s Supervisory Control and Data Acquisition (SCADA) system via a cellular modem system (or other telecommunications system acceptable to NS Power) to provide the Generating Facility’s operational data and status, for each time interval of 10 minutes.

### 6.18.2. *Supervisory Control and Data Acquisition (SCADA)*

All Generating Facilities with a Generating Facility Capacity greater than or equal to 5 MW shall be equipped with real time communications facilities to enable connection to NS Power’s SCADA system for telemetering of the generator real and reactive power output, indication of device status, and real time device control. All Generating Facilities with a Generating Facility Capacity greater than or equal to 1MW and less than 5MW shall be reviewed in the DSIS to determine if similar remote-control functionality is required.

If deemed necessary by the DSIS, the capability to curtail generation may be required.

## 7. **Metering**

### 7.1. *Revenue Metering*

Revenue-class Metering Equipment will be supplied, installed and maintained in accordance with Section 2.5 of the SSGIA.

Power flows to and from the Generating Facility shall be measured at, or at NS Power's option, compensated to, the Point of Interconnection to ensure that all required billing quantities are recorded as necessary for application of NS Powers' tariffs or power purchase agreements. Unless otherwise agreed by the Parties, NS Power will install Metering Equipment at the Point of Interconnection prior to any operation of the Generating Facility and shall own, operate, test and maintain such Metering Equipment.

The Interconnection Customer shall be responsible for all costs associated with the purchase, installation, operation, replacement, testing and maintenance of the Metering Equipment.

All revenue Metering Equipment installations shall at all times meet the requirements of Good Utility Practice and all Applicable Laws and Regulations. The Generating Facility, if required, must provide and install at Generating Facility's expense, and in accordance with NS Power Metering Standards<sup>11</sup>, meter sockets and metering cabinets in a suitable location to permit access to Metering Equipment by NS Power.

## **8. General Operating Requirements**

NS Power requires operational control over any Interconnection Facilities it deems necessary to ensure reliability or serviceability of the Distribution System.

An Interconnection and Operating Agreement in the form of the SSGIA shall be executed between the Interconnection Customer and NS Power to identify responsibilities, key contacts, desired operating characteristics, and other relevant operating considerations prior to the interconnected operation of the Generating Facility.

### **8.1. Testing**

All protective devices or functions supplied to satisfy the requirements in Section 6 shall be routinely tested by qualified personnel at the Interconnection Customer's expense. Each routine check shall include both a calibration check and an actual trip of the circuit breaker or contactor from the device being tested. A test report shall be prepared listing the tests made and the "as found" and "as left" calibration values. Copies of all test reports will be made available to NS Power.

Special tests may also be requested by NS Power to investigate apparent mis-operations that have had an adverse effect on the Distribution System. Costs of such tests will be at the Interconnection Customer's expense.

## **9. Responsibility for Costs**

The Interconnection Customer is responsible for all capital, operating and maintenance costs of all equipment on the generator side of the Point of Interconnection.

Where upgrades and/or revisions are required to the existing Distribution Systems to accommodate the generation addition, the Interconnection Customer shall pay the actual cost of the installation/changes. The Interconnection Customer shall pay a capital contribution for any required line extensions and right of way acquisition necessary to extend the Distribution System to the Generating Facility. If this line is dedicated to serve the Interconnection Customer, all maintenance, repair and replacement costs are the responsibility of the Interconnection Customer. NS Power will perform and manage the maintenance of these facilities.

## Appendix A – Open Phase Protection Requirements

**Table A1 - Open Phase Protection Requirements (Refer to Section 6.16)**

HV-LV Core	Grounding	Required Switchgear (1)	HV (2) Protection	LV (2) Protection	Gen (2) Protection	Notes
YgYg 4/5-leg	Gen Reactor	Either 52HV + (52Gen or 52LV) OR 52LV+52Gen	50/51 59N 46	50/51 59N 47	81 27/59 50/51G 51V 46 47	Backup provided by trips to HV and LV breakers
	LV Gnd Tfr	Either 52HV + (52Gen or 52LV)	50/51N 59N 46	50/51N, 59N 46 47	81 27/59 50/51N 51V 46 47	Backup provided by trips to HV and LV breakers
		OR 52LV+52Gen	_____	50/51N, 59N 46 47	81 27/59 50/51N 51V 46 47	
HV Gnd Tfr	52HV + (52Gen or 52LV)	50/51N 59N 46	_____	81 27/59 50/51N 51V 46 47		

(1) Minimum requirements to provide protection and backup

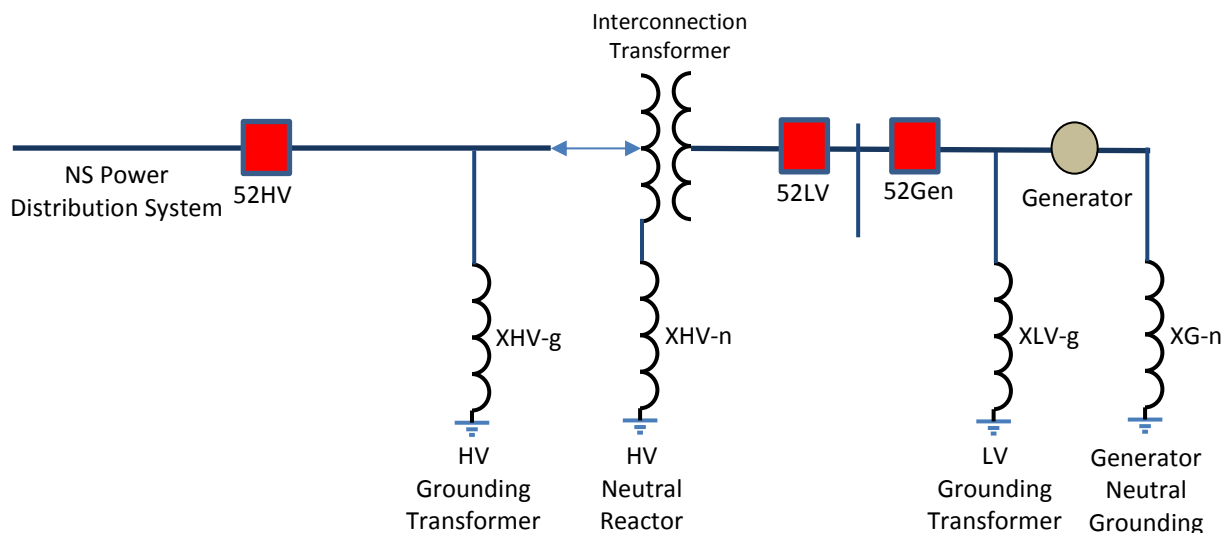
(2) HV and LV protection are the protections required for the interconnection. Generator protection may be adequate in place of the LV protection where an HV circuit breaker and protections are provided.

(3) Protection Nomenclature:

81	Over/Under Frequency
27/59	Over/Under Voltage
50/51N	Phase Instantaneous Overcurrent/Neutral Time Overcurrent
51V	Voltage Restrained Time Overcurrent
46	Reverse-Phase or Phase Balance Current Relay or Stator Current Unbalance
47	Phase-Sequence or Phase Balance Voltage
52	Isolating Devices

### General Interconnection Grounding Arrangement

(Not all elements shown in this diagram are required in every case)



## Appendix B – References

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- <sup>1</sup> NS Power “Standard Small Generator Interconnection Agreement (SSGIA)” – Current version posted to NS Power OASIS.
- <sup>2</sup> NS Power’s Standard Protection Code – Latest version
- <sup>3</sup> Province of Nova Scotia “Electrical Installation and Inspection Act” R.S.N.S. 1989, c. 141
- <sup>4</sup> CSA Canadian Electrical Code Part 1, C22.1-02, Safety Standards for Electrical Installations (CE Code)
- <sup>5</sup> CSA Standard CAN3 C235-83 (R2010)– “Preferred Voltage Levels for AC Systems 0 to 50,000V”
- <sup>6</sup> IEEE 519 – 2014: Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems
- <sup>7</sup> IEEE 1547-2018 - Standard for Interconnecting Distributed Resources with Electric Power Systems
- <sup>8</sup> NPCC Regional Reliability Reference Directory #12 Under Frequency Load Shedding Program Requirements, July 9, 2013
- <sup>9</sup> NERC Standard PRC 024-2 Generator Frequency and Voltage Relay Settings Version 1 (Attachment 1 – Off Nominal Frequency Capability Curve)
- <sup>10</sup> CSA C22.3 No 9:20 Interconnection of distributed energy resources and electricity supply systems
- <sup>11</sup> Nova Scotia Power Inc “Metering Standards” Current Version