*Sask**Power***

NON-UTILITY GENERATION INTERCONNECTION REQUIREMENTS AT VOLTAGES 25 kV AND BELOW

2000 October

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1. INTRODUCTION

1.1. Intent

This document:

- Defines the technical requirements for connecting generation that is not exclusively owned by SaskPower but is connected to SaskPower facilities which have an operating voltage of 25,000 volts or lower.
- Does not constitute a guide or design handbook. Non-Utility Generation (NUG) Owners who are considering the development of a generation facility intended for connection to the SaskPower distribution system should engage the services of individuals qualified to provide design and consulting services for electrical interconnection facilities.

1.2. Purpose

The purpose of the interconnection guideline is to facilitate the technical assessment of interconnection requirements for parallel operation of non-utility generation facilities. The information provided in this document should allow potential NUG owners to conduct feasibility studies to assess the technical requirements for interconnection.

This document contains information pertaining to the characteristics of SaskPower's distribution system and identifies potential issues, such as safety, power quality, protection coordination, reliability, and operation, which should be considered at various stages of the project. This document also outlines the major steps in the process of connecting a non-utility generator to SaskPower's distribution system.

This document does not constitute an offer to or express an interest in purchasing capacity and energy from non-utility generation projects. It does not set out the basis for commercial agreements related to the delivery of electrical energy and capacity from non-utility generation projects. Please refer to the most recent version of SaskPower's Non-Utility Generation Policy for this information, or contact:

Senior Engineer, Independent Power Producer Options
Customer Services
SaskPower
2025 Victoria Avenue
Regina, Sask.
S4P 0S1

1.3. Scope

The scope of this document covers non-utility generation not exclusively owned by SaskPower but which is connected to and operates in synchronism with SaskPower's distribution system. This document does NOT cover interconnection to SaskPower facilities that operate at voltages above 25 kV. For interconnection to the transmission system refer to SaskPower's document "Non-Utility Generation Interconnection Requirements at Voltages 72kV and Above".

The use of the term "Distribution System" within this document is specific only to this document. The use of these terms and definitions is not intended to define SaskPower facilities other than for the purposes described above.

This document covers three-phase generation at single site installations with a total installed capacity of up to 1000 kW and single-phase generation at single site installations with a total installed capacity of up to 100 kW. Three phase generation projects greater than 1000 kW will be considered, but the complexities of such installations are such that they cannot be addressed in a general requirements document such as this. NUG proponents who are assessing installations

with an installed capacity greater than 1000 kW should contact SaskPower to discuss the specifics of their project.

1.4. Ownership and Payment For Facilities

SaskPower will own, maintain and operate all facilities on SaskPower's side of the point of delivery. The NUG Owner is responsible for the supply, installation, ownership, maintenance, testing (including periodic re-testing) and operation of all facilities on the generation side of the point of delivery. The exception to this may be provision of communication and SCADA facilities as noted in Sections 3.3 and 3.4. The aforementioned division in responsibilities does not extend to the responsibility for costs associated with the interconnection facilities. **The NUG Owner is responsible for the total cost of the Interconnection Facilities required to integrate the NUG Facilities into the SaskPower distribution system. The NUG Owner is also responsible for the costs of future changes to the NUG Facilities as may be required by SaskPower.**

1.5. Agreements, Approvals, and Permits

1.5.1. Agreements:

Prior to the connection of NUG Facilities to the SaskPower distribution system, the NUG Owner agrees to:

1. For generators 100 kW and less in size, sign an Interconnection Agreement For Small Generators.
2. For generators greater than 100 kW in size, sign a Service And Supply Agreement with SaskPower.
3. Sign an Operating Agreement with SaskPower which agreement shall outline standard operating practices. Please refer to Appendix "D" for a detailed outline of the requirements of the Operating Agreement.
4. Attend an operations meeting upon notice from SaskPower for the purpose of establishing procedures and permits for the initial electrical connection between the NUG Facilities and the SaskPower distribution system.
5. **NUG Owners with generators greater than 100 kW in size, who are engaging in self-generation, must demonstrate that they have made arrangements for reserve requirements (spinning and non-spinning reserve) specified by SaskPower.**

1.5.2. Approvals and Permits:

Notwithstanding subsection 3(2)(a) (i) of *The Electrical Inspection Act, 1993,* the NUG Owner agrees to complete the following:

1. Ensure that the design of the generation facilities and equipment installed is compliant with the Canadian Electrical Code;
2. Submit for inspection its interconnection facilities by SaskPower's Electrical Inspection Division;
3. Pay to SaskPower's Electrical Inspection Division any inspection rate or fees established by the Electrical Inspection Division as compensation for the inspection of the interconnection facilities;
4. Comply with any other instructions issued by SaskPower respecting safety, system protection, operating procedures and schedules for operation and maintenance.

In addition, the NUG Owner shall be responsible for determining requirements for, and obtaining any licenses, permits or approvals necessary to ensure compliance with any federal, provincial or municipal statutes and regulations.

The NUG Owner shall comply with any other instructions issued by SaskPower respecting safety, system protection, operating procedures and schedules, testing of all or portions of the facility as part of the operation and maintenance of the NUG Facility.

1.6. Waiver

The NUG Owner acknowledges and agrees that the above requirements, including any reviews conducted by SaskPower or the SaskPower Electrical Inspection Division, are done at the sole risk and expense of the NUG Owner.

1.7. Changes to Facilities

Prior to undertaking changes to any NUG interconnection facilities, which would alter the performance of the interconnection, agreement must be obtained from SaskPower.

1.8. Interconnection Process (Technical Assessment)

The following outlines the general process to be followed for dealing with the technical issues associated with all requests to operate generation in parallel with SaskPower's system.

- NUG proponent submits a **Request for Preliminary Integration Study** (information requirements are set out in Appendix B).
- SaskPower will undertake a steady state analysis of the system and provide a preliminary assessment of the interconnection requirements along with budget level (± 20%) cost estimates for the interconnection facilities within 60 working days. SaskPower will assess a fee for conducting the preliminary assessment.
- Following the preliminary assessment, if the NUG proponent determines that there is a basis for proceeding with the project, a **Request for Formal Integration Study** (Integration Studies) shall be submitted which includes the information requested in Appendix C. SaskPower will conduct the detailed Integration Studies within sixty (60) working days to confirm the connection configuration and identify any additional or special requirements. It should be noted that for projects requiring new power lines, there may be a significant lead time requirement. SaskPower will assess a fee for conducting the Integration Studies.

The purpose of the Integration Studies carried out by SaskPower is to identify the interconnection facilities that have to be added to SaskPower's system to accommodate the proposed NUG project along with their cost. The Integration Studies also assess whether the proposal by the NUG proponent meets SaskPower's technical requirements for interconnection. The Integration Studies carried out by SaskPower do not replace the design studies that must be carried out by the NUG proponent.

1.9. Information

The information contained within this document is subject to change. An updated copy of this document is available upon request. Contact SaskPower at 2025 Victoria Avenue, Regina, Saskatchewan S4P 0S1, and direct your inquiry to the Vice President and General Manager of the Transmission and Distribution Business Unit.

2. SASKPOWER DISTRIBUTION SYSTEM CHARACTERISTICS

The following information describes the characteristics of the SaskPower distribution system and identifies a number of aspects that must be taken into consideration in the design of any generating facility to be interconnected with SaskPower's distribution system.

For the purposes of this document, the term 'Distribution System' may mean SaskPower's three phase 25 kV, and 14.4 kV systems, single phase 14.4 kV system, or 120/240 volt single phase secondary distribution system.

2.1. General System Configuration

The majority of SaskPower's primary three-phase distribution system operates at a nominal voltage of 25 kV phase-to-phase. SaskPower also utilizes three-phase, 14.4 kV phase-to-phase as a primary distribution voltage in some urban areas. The SaskPower primary distribution system is supplied from substations which are equipped with two winding step-down transformers, which are Δ Y connected (solidly grounded Y on the 14.4 kV or 25 kV winding). The primary distribution system operates as a radial feeder system with a single point of supply. Some feeders may have alternate points of supply, but they will be operated with both points of supply closed only momentarily during switching operations. The 25 kV system is used to supply an extensive single-phase, ground-return primary distribution system that operates at 14.4 kV phase-to-ground.

In some communities, SaskPower also utilizes three-phase primary distribution systems that operate at 2.4 kV and 4.16 kV phase-to-phase. The application of these systems is limited. Information on the characteristics of these systems can be obtained from SaskPower.

In urban environments, SaskPower provides 120/240 volt single phase secondary distribution. The ability of the secondary distribution system to integrate distributed generation is extremely limited.

2.2. Frequency and Frequency Variation

The nominal frequency of the SaskPower system is 60 Hz. During steady state operation, frequency deviations are within $\pm$ 0.02 Hz. Frequency excursions outside of the above range will occur during disturbances.

2.3. Voltage Variation

The SaskPower operating voltages vary from nominal for a number of reasons including load variation, and contingency situations. During normal operating conditions, the voltage at the point of delivery on the 25 kV and 14.4 kV three phase systems and 14.4 kV single phase system can vary from 94% to 106% of nominal voltage. During normal operating conditions, the voltage at the service entrance on the 120 / 240 volt secondary distribution system can vary from 91.6% to 104.2% of nominal voltage. During abnormal conditions, the voltage variation on all systems can temporarily exceed these values.

2.4. Abnormal Voltages

The distribution system is subject to temporary abnormal voltages. Aside from the voltage unbalance conditions described in Section 2.5, voltage transients and swells can occur on the distribution system. These can be caused by such phenomena as lightning strikes, single phase to ground faults and the loss or switching of customer load. The project NUG Owner must insure that the insulation levels, or protective apparatus (surge arresters, etc.) employed in their facilities are capable of withstanding typical abnormal voltages on a distribution system.

2.5. System Voltage Unbalance

Phase to phase voltage unbalance can be expected on the primary distribution system. During normal steady state operation, phase to phase voltage unbalance is normally less than 3%. In some rural locations, unbalances may be higher. The NUG Owner should check with SaskPower to obtain site specific details. Voltage unbalance is defined as follows:

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

as derived from NEMA MG1-14.34.

During faults on SaskPower's system and within single pole reclosing cycles, the momentary unbalance may be greater than defined above. SaskPower will not be responsible for damage to NUG facilities due to voltage unbalance.

2.6. Fault Clearing

Where reference in this document is made to fault clearing times, it shall mean the time from the inception of the fault until interruption of the fault current.

The time required to clear faults on the Distribution System varies. For the 25 kV and 14.4 kV systems, line to ground faults, which constitute a large portion of the faults, the time to clear a fault will normally be less than 1.0 second. For phase to phase faults and high impedance ground faults, the clearing time could be up to 3 seconds. The addition of a generation source on these systems, which are radial systems, may require an improvement (shortening) of fault clearing time or recoordination of SaskPower's protection systems.

The fault clearing times suggested above are based on the equipment operating as designed; however, if faults are cleared by backup protection, the clearing time in all instances would be expected to increase.

2.7. Auto Reclosing

The SaskPower 25 kV three phase and 14.4 kV single phase Distribution System utilizes multi-shot auto-reclose to clear non-permanent faults. Reclose dead times can vary from instantaneous reclose to 5 seconds. Interrupting devices may trip a single phase or all three phases, depending on the application. In the event of a permanent fault, all three phases of the interrupting device will be tripped regardless of whether it is a single phase or three-phase fault.

Single phase tripping and reclose on interrupting devices may cause unbalanced loading and / or shock loading during the trip / reclose cycle.

2.8. Frequency of Power Interruptions

As is normal practice in the utility industry, SaskPower's primary distribution system utilizes unshielded construction with insulation levels appropriate to withstanding expected power frequency voltages. As such, direct lightning strikes to distribution power lines, or nearby ground lightning strokes will usually result in a flash over of the insulators on the power line, resulting in tripping by SaskPower's protection systems. If the fault is temporary, service may be restored by SaskPower's auto reclose system.

Because of the type of construction, and the length of some of the primary distribution feeders in SaskPower's system, the frequency of power interruptions, whether they are momentary (successful auto reclose), or sustained (permanent fault), can be high. The NUG Owner should take this into consideration when assessing:

- the requirement for staffing the facility,
- the requirement for monitoring and remote control of the facility,
- the requirement for auto restart,

- the impact of trips on the reliability of the facility, and
- the economics of the project.

2.9. System Grounding

The SaskPower distribution system has been designed to operate as "effectively grounded".

2.10. System Fault Levels and System Impedances

The fault levels on the SaskPower systems, which are influenced by numerous factors, including location, generation pattern, and contingencies, vary within a broad range of values. Future fault levels will also be influenced by system expansion. NUG proponents must design their facilities to withstand the fault contribution from SaskPower's system. The expected fault contribution from SaskPower's distribution system along with the SaskPower system impedance for a site being considered for a NUG project can be obtained from SaskPower

3. GENERAL REQUIREMENTS FOR ALL NUG PROJECTS

The following general requirements apply to all non-utility generation projects interconnected with SaskPower's Distribution System.

3.1. System Unbalance

In the presence of voltage unbalance, generator output may have to be reduced to avoid overloading the generator. The NUG Owner must take into consideration that most locations on SaskPower's distribution system have a degree of continuous voltage unbalance (as specified in Section 2.5), and specify the rating of their generator appropriately to allow them to deliver planned output. The generator must also be able to withstand the effect of voltage unbalances resulting from system disturbances. The most common cause of system unbalance on the distribution system resulting from disturbances will be unbalanced powerline faults and single pole tripping and reclose.

3.2. Frequency Variation

The NUG generator shall be able to operate over a frequency range of 59.5 Hz to 60.5 Hz without tripping.

3.3. Power Islanding

Power islanding is the condition where the NUG facilities and a portion of SaskPower's distribution system have become isolated from the rest of SaskPower system, and continue to operate in an isolated mode. SaskPower's requirement is that the NUG facilities connected onto SaskPower's distribution system not be permitted to operate as a power island connected with SaskPower customers. All NUG facilities shall be equipped with protection systems, which detect a power island, condition and trip the generator off-line. In some circumstances this may require modification to SaskPower's facilities and, or, the installation of special communication and protection schemes to send direct trips to the NUG generator.

3.4. Protection of Equipment and Detection of Faults

The proper detection of all types of faults, which occur either on SaskPower's distribution system or within the NUG facilities and the disconnection of the NUG facilities from SaskPower in such events is critical for reasons of safety and protection of equipment. The NUG Owner is responsible to insure that the NUG facilities are equipped with protection systems that will detect and isolate the NUG facilities from SaskPower's distribution system during such events.

Fault clearing time requirements for faults on SaskPower's distribution system shall be determined on an individual case basis. The NUG facilities may be required to be equipped with protection systems that are zoned or time graded to facilitate coordination with SaskPower's protection systems for faults on adjacent facilities to which the NUG interconnection facility is not directly connected. At SaskPower's determination, dedicated communication facilities to the NUG site may be required, at the cost of the NUG owner, to facilitate timely clearing of faults. Dedicated secure communications may also be required to remove the fault infeed from the NUG for faults on adjacent lines in the event of a breaker failure at a remote location.

3.5. Protection Coordination

The NUG facility protection systems shall coordinate with the SaskPower protection systems. The NUG Owner shall submit proposed fuse types or relay settings to SaskPower for review and acceptance. Any subsequent relay setting changes shall also be submitted to SaskPower.

3.6. Protection From Abnormal Conditions

NUG interconnection facilities shall be adequately protected from, or able to withstand abnormal conditions on SaskPower's distribution system. This may include, but is not limited to:

- frequency excursions due to disturbances on SaskPower's distribution system,
- partial or complete loss of load as a result of disturbances on the SaskPower's distribution system
- transient overvoltages as a result of lightning, or switching events, and
- overvoltages due to resonance conditions, healthy phase voltage rise during faults, self excitation, loss of load

The NUG facility must be self-protecting to prevent damage as a result of the normal or abnormal operation of the SaskPower grid. The NUG Owner is accountable for the execution of studies to identify potential abnormal conditions and the cost of mitigating against the effects of abnormal conditions.

3.7. Voltage Variations (Flicker)

The NUG Owner is required to ensure that the operation of the NUG facility will not cause voltage variations on SaskPower's system that could result in excessive lamp flicker for SaskPower's customers. If the NUG facility utilizes a prime mover that has a fluctuating power output (wind power, slow speed reciprocating engine, etc.), the NUG Owner must insure that the fluctuations in power output do not cause voltage variations which exceed SaskPower's acceptable limits. The voltage variation limits, as measured at the point of delivery, are defined in the SaskPower Electric Service Guide, Section 1.2.10b).

The NUG Owner should ensure that the NUG facility can tolerate the voltage variation that is permitted on SaskPower's distribution system as defined in the SaskPower Electric Service Guide, Section 1.2.10b).

3.8. Voltage Distortion

If the NUG Owner plans to utilize a synchronous generator, the limit on the distortion of the voltage waveform generated shall be in accordance with the general requirements for synchronous machines as described in ANSI G50.10 1990 or most recent update.

3.9. Harmonic Currents

The current that flows at the Point Of Delivery shall have a harmonic content, which falls within the limits, specified in Section 1.2.10 c) of SaskPower's Electric Service Guide.

3.10. Provision for Future Changes

The NUG Owner is responsible to keep abreast of future business environment and technical changes and to undertake these changes to the NUG Facilities. In addition, when advised by SaskPower, the NUG Owner will make changes requested by SaskPower to the NUG Facilities.

The NUG Owner is responsible for making required changes to the NUG Facilities in response to meet new or revised standards or due to system changes, and therefore make provision to accommodate changes efficiently. The NUG Owner shall be responsible for the cost of any required changes, including those changes requested to be made by SaskPower.

4. INTERCONNECTION REQUIREMENTS FOR NUG PROJECTS UP TO AND INCLUDING 100 kW IN SIZE

The following sets out the requirements for distribution connected generating facilities, with a total installed capacity up to 100 kW (total installed capacity at the site). Installations with a total installed capacity greater than 100 kW, or which use a synchronous generator of any size, must meet the requirements set out in Section 5 of this document.

4.1. Generator Type and Size Limits

Single-phase and three-phase generators may be connected to the primary distribution system. The maximum permissible size for single-phase generators connected to SaskPower's primary distribution system is **100 kW**. Depending on the location of the facility, there may be other restrictions that limit the maximum size of a single-phase generator. Only single-phase generators can be connected to the secondary distribution (120/240 volt) system. The maximum permissible size for single-phase installations connected to the secondary distribution system is **5 kW**.

SaskPower requires that generators up to 100 kW in size must not be able to operate in an isolated power island connected with SaskPower customers, or contribute sustained (beyond 10 cycles) fault current to the SaskPower system during a fault on SaskPower's primary or secondary distribution system. As such, voltage source generators are not permitted for use in applications less than 100 kW in size. The only types of 'generators' permitted will be induction generators or generation technologies that utilize non self-commutating power inverters. This generally precludes the use of generators that are part of packaged back-up, stand-by or portable power plants.

4.2. Point of Delivery

For NUG facilities connected to SaskPower's primary distribution system, the point of delivery will be SaskPower's side of the high voltage isolating switch. For NUG facilities connected to SaskPower's secondary distribution system, the point of delivery will be the metering point at the service entrance.

4.3. NUG Interconnection Facility

The NUG interconnection facility shall comply with the requirements of Sections 4.1, 4.2, and 4.4 of SaskPower's Electric Service Guide. Where conflicts exist between Sections 4.1, 4.2, and 4.4 of SaskPower's Electric Service Guide and this document, this document shall prevail.

4.4. NUG Facility Isolating Device

4.4.1. For NUG Facilities Connected to SaskPower's Primary Distribution System

Maintenance, safety, and system considerations require a visible break disconnect device to disconnect the NUG interconnection facilities from SaskPower's facilities. The disconnect device shall be connected on SaskPower's side of the NUG interconnecting transformer. The device shall be accessible and lockable by SaskPower staff. The device must be accessible by SaskPower on a 24-hr basis without prior notice to the NUG Owner. Switches located inside locked facilities are not acceptable. Switches on NUG facilities where H_2S is present shall be located outside of the hazardous area.

Those customers engaging in self-generation who have purchased stand-by service from SaskPower may elect to provide a secondary voltage, visible break, isolating switch for their generator to avoid an outage to their load. This shall be in addition to the primary isolating device. The switch shall be accessible and lockable by SaskPower staff. The switch must be accessible by SaskPower on a 24-hr basis without prior notice to the proponent.

Switches located inside locked facilities are not acceptable. Switches on NUG facilities where H_2S is present shall be located outside of the hazardous area.

4.4.2. For NUG Facilities Connected to SaskPower's Secondary Distribution System

The NUG facilities shall be provided with a disconnect switch which must isolate both hot legs and neutral. The disconnect switch may be located on the customer's side of the metering point or between the generator and the customer's service panel if the generator is connected into an existing service. The switch must provide a visible break, be lockable and accessible by SaskPower staff on a 24-hr basis without prior notice to the NUG Owner. Switches located inside locked facilities are not acceptable.

4.5. NUG Facility Fault Interrupting Device

4.5.1. For NUG Facilities Connected to SaskPower's Primary Distribution System

The NUG facility shall be equipped with a fault interrupting device on the SaskPower side of the transformer which, in the event of a fault within the transformer or the NUG facilities, is capable of interrupting the fault current and isolating the NUG facilities from SaskPower's distribution system. Fuses are acceptable for this application. The proponent should assess the risk of damage resulting from single phasing of the transformer in the event of a single fuse failure. Where fused protection is used on the high side of the transformer, the NUG substation shall be equipped with a low voltage circuit breaker or contactor for tripping the generator.

The NUG Owner is responsible for insuring that the high voltage fault-interrupting device coordinates with SaskPower's feeder protection. The NUG Owner shall submit proposed relay or fuse settings to SaskPower for review of protection coordination.

4.5.2. For NUG Facilities Connected to SaskPower's Secondary Distribution System

All NUG facilities connected to the secondary distribution system require a device, which in the event of a fault within the NUG facility is capable of interrupting the fault current and isolating the facility from SaskPower's system. A dedicated NUG facility will require fuses or a molded case type circuit breaker. This may be located on the generator side of the metering point. NUG facilities in which the power source is integrated into an existing electrical service may rely on the molded case circuit breakers within the service panel.

4.6. Transformer Requirements

For three phase installations, the transformer winding configuration shall be grounded Wye on the 25 kV system with a grounded or ungrounded Wye on the low voltage side. The grounded Wye connection on the low voltage side is only acceptable if the generator has a Delta or ungrounded Wye winding connection.

4.7. Metering Requirements

The metering will be located on the secondary side of the transformer and compensated for losses to the Point-of-Delivery. Dual register, revenue approved metering will be required to measure the power and energy supplied by SaskPower to the NUG, as well as power and energy supplied by the NUG to SaskPower.

4.8. Required Protection

The NUG generator shall be equipped with the protection set out in Sections 4.8.1 through 4.8.4. The NUG Owner shall submit proposed settings for all required protection to SaskPower for review of protection coordination. In the following sections, the term 'relay' is used in a general sense. It is recognized that some NUG technologies may utilize packaged protection systems that integrate the protection functions into one device, rather than utilizing individual 'relays'.

4.8.1. Over current Protection

All NUG projects shall be equipped with over current protection to trip the generator off in the event of a fault on SaskPower's system or a fault within the generator.

4.8.2. Over and Under Frequency Protection

All NUG projects shall have under and over frequency protection relays that will disconnect the generator from SaskPower's system if the frequency deviates from 60Hz. The normal trip settings are frequencies of 59.5 Hz and 60.5 Hz sustained for more than 0.5 seconds.

4.8.3. Over and Under Voltage Protection

All NUG projects shall have under and over voltage protection relays which will disconnect the generator from SaskPower's system in the event of abnormal voltages. The under-voltage trip setting shall be adjustable over a range of 85% to 100% of nominal. The over-voltage trip setting shall be adjustable over a range of 105% to 115% of nominal. The under voltage and over voltage protection shall have adjustable time delays. The time delay shall be independently adjustable for the over and under voltage trip settings. It may be advantageous to provide a separate instantaneous or very high speed over voltage protection for the detection of self-excitation or ferroresonance conditions.

4.8.4. Power Flow Relay

NUG owners who are generating to displace load, but do not have a service agreement covering the provision of standby service from SaskPower, shall have a power flow relay which isolates the load and generation from SaskPower's system in the event of power flow into the customer's facility. A time delay of up to 5 seconds on this relay is permissible to minimize nuisance trips.

4.9. Additional Protection

The NUG Owner is responsible to evaluate the requirement for protection schemes to be applied to the generator. In addition to the required protection set out in Section 4.8, it is recommended that the NUG Owner evaluate the requirement for the following protection schemes:

4.9.1. No-volts Auto-Reclose Protection

SaskPower applies auto-reclose to its primary distribution system. If the generator cannot withstand the reacceleration that will occur following reclose, it is recommended that the generator be equipped with a no-volts relay that trips the generator off during the reclose dead time.

4.9.2. Unbalance Relay

For three phase generators, it is recommended that an unbalance or negative sequence relay be installed that trips the generator off on excessive unbalance. This is particularly important if fused protection is used on the primary of the NUG transformer.

4.9.3. Rate-of-Change of Frequency Relay

The application of a rate-of-change of frequency relay may be a suitable means of detecting a power island condition. The NUG Owner shall submit proposed settings to SaskPower for review.

In the preceding sections, the term 'relay' is used in a general sense. It is recognized that some NUG technologies may utilize packaged protection systems that integrate the protection functions into one device, rather than utilizing individual 'relays'.

4.10. Auto Resynchronization

Following the trip of the feeder to which the generator is connected, the generator may automatically restart and resynchronize following successful restoration of **normal** voltage to the distribution circuit. If auto resynchronization is to be attempted, the generator must be equipped with a relay that senses the presence of normal voltage for a period of time, typically five minutes. Normal voltage is defined as being within 94% to 106% of nominal. The time period must be adjustable between 1-60 minutes and will be determined by SaskPower. If multiple generators exist on any one distribution feeder, SaskPower reserves the right to stagger generator automatic restart times.

4.11. Voltage Deviations Caused by NUG Facility

SaskPower sets requirements in terms of limiting the voltage sags, swells, and flicker caused by the operation of customer equipment. The NUG Owner must design its equipment and control its operation to ensure that it does not exceed these limits.

Induction generators and non self commutating inverters are unable to generate power before they are connected to the utility system and therefore, there is no real synchronization required. The induction generator may be used as a motor to accelerate the prime mover to operational speed. If the NUG generator is to be brought up to speed using across the line starting from SaskPower's system, the maximum voltage drop during starting at the Point Of Delivery must be limited to 8% or less. This is assuming that the NUG generator is started less frequently than once per day. For more frequent starts refer to the voltage flicker limits set out in Section 1.2.10 b) in SaskPower's Electric Service Guide. As an alternative to across the line starting, the NUG generator may be closed onto the SaskPower system after it has been brought up to near synchronous speed using the prime mover. The voltage deviation that results from the connection of the NUG generator to SaskPower's system using this starting technique must also meet the preceding limits.

The voltage change that results from the disconnection of the NUG generator from SaskPower's system must be limited to 8% or less at the Point Of Delivery. This is assuming that the generator is disconnected (planned disconnection or unplanned trips) less frequently than once per day. If more frequent trips are anticipated, or actual experience indicates that trips are more frequent, the acceptable voltage deviation will be defined by the voltage flicker limits in SaskPower's Electric Service Guide. To minimize disturbances to other customers, SaskPower requires that for planned shutdown (not initiated by a protection system) of the NUG generator, the output of the NUG generator should be reduced to zero before the NUG generator is disconnected from SaskPower's system.

SaskPower's limits on voltage deviation may determine the maximum size of NUG generator that can be installed in a particular location.

4.12. Power Factor Control Requirements

For the purposes of clarification, leading power factor operation of a generator means that the generator is drawing reactive power off of the distribution system.

Voltage regulation on distribution circuits is required in order to maintain the service supply voltage for end-use customers within acceptable limits. Uncompensated induction generators and inverters are seen by the distribution system as a reactive power load, which affects voltage control on the distribution system. Unless SaskPower indicates otherwise, induction generators and inverters that are greater than 25 kW in size (based upon the total installation size) must be equipped with power factor correction equipment to be installed at the NUG Owner's expense. Generators less than 25 kW in size (based upon the total installation size) should not have power factor correction equipment.

The inverter / induction generator must normally be equipped with sufficient power factor correction capacitors to correct the full load power factor to 0.90 leading. The power factor

correction capacitors must normally be provided in steps to follow the output of the generator. Sufficient steps shall be provided to maintain the power factor of the generator between 0.90 leading and 0.95 leading over the expected power output range. The power factor at very low generator outputs (less than 5% of rated output) may drop below 0.90 leading. The capacitor switched in at start up shall be sized to meet the voltage deviation requirements set out in Section 4.6 of this document.

The power factor controller shall have a voltage override that causes it to switch out capacitors if the voltage at the Point Of Delivery exceeds an upper limit to be specified by SaskPower. The normal upper limit is 105% of nominal; however, the power factor control equipment shall have provision to adjust this upper limit between 100% and 110% of nominal. The power factor control equipment shall also have provision for a time delay between sensing an excursion of the upper voltage and initiating control action. The power factor control equipment shall have provision to allow for the adjustment of this time delay between 0 and 180 seconds. The required time delay will be specified by SaskPower.

4.13. Power Island Operation via Self Excitation of the Generator

Self-excitation of an induction generator is a condition where there is sufficient capacitance connected to the terminals of the generator to provide excitation current to the generator which will maintain a voltage on its terminals after it has been isolated from the power system. This exciting current can be provided by local power factor correction capacitors or, if the generator is isolated along with a portion of SaskPower's distribution system (a power island), the feeder line capacitance and any capacitors on SaskPower's system.

The NUG Owner must ensure that its facility will not sustain a power island through self-excitation of its generator. Aside from the danger to SaskPower staff of an unexpected power island, the voltages that occur in a power island resulting from self-excitation are uncontrolled, and may result in apparatus damage.

For NUG installations that are 100 kW or less in size, local protection schemes at the NUG facility is normally acceptable for the detection of, and subsequent isolation from power island conditions.

Unless the NUG Owner can demonstrate through the execution of analytical studies, that there is no risk of self-excitation of the generator, the NUG Owner must demonstrate, to SaskPower's satisfaction:

- that the NUG protection systems are capable of detecting a power island condition,
- that in the event self-excitation, isolation of the NUG will occur quickly enough to preclude damage to other customers or SaskPower's system from the abnormal voltages that may occur, and
- that the interrupting device used to separate the NUG generator from SaskPower's power system is capable of operating at the elevated voltages which may occur following self-excitation,

Failure to meet the preceding requirements may mean that the NUG Owner is responsible for the cost of installing special protection schemes. This may include a direct trip signal from SaskPower's source substation to the NUG Owner's facility or other generation facilities on the feeder whenever there is a trip on the feeder to which the NUG is connected.

In assessing the opportunity for a self-excited power island, the total amount of capacitance on the feeder to which the NUG is connected must be taken into consideration. This includes power factor correction capacitors at the NUG site, discrete capacitors on the feeder, and the distributed capacitance of the feeder itself. The assessment must also take into consideration the presence of existing generators on the same feeder along with the minimum load likely to be connected to the feeder. SaskPower will provide information on load, feeder characteristics, and the location of capacitors on its system to facilitate assessment of the risk of self-excitation. Such details are site specific.

5. INTERCONNECTION REQUIREMENTS FOR GENERATORS GREATER THAN 100 kW IN SIZE

The following sets out the requirements for generators that are greater than 100 kW and up to 1000 kW in size.

5.1. Generator Type and Size Limit

Only three-phase generators are permitted above 100 kW.

SaskPower's objective is to minimize the impact of distributed generation connected on the operation of its distribution system. It is also SaskPower's objective to minimize or avoid the use of apparatus, communication systems, or protection schemes that are not normally applied at distribution voltages. **Therefore, SaskPower strongly recommends against the use of synchronous generators or other generator technologies that can act as voltage sources**. Synchronous generators act as sustained sources of fault current which complicates, or may preclude the coordination of the protection systems on the distribution system. Synchronous or voltage source generators can support power islands, which is an unacceptable operating condition. To deal with the adverse impact of synchronous or voltage source generators will likely require the application of communication or protection schemes that are not normally applied at the distribution level. Aside from their complexity, the cost of these schemes is likely to be excessive relative to the cost of the NUG project, which may adversely affect the economics of the project.

5.2. Point of Delivery

For NUG facilities connected to SaskPower's primary distribution system, the point of delivery will be SaskPower's side of the high voltage isolating device.

5.3. NUG Interconnection Facility

The NUG interconnection facility shall comply with the requirements of Sections 4.1, 4.2, and 4.4 of SaskPower's Electric Service Guide. Where conflicts exist between Sections 4.1, 4.2, and 4.4 of SaskPower's Electric Service Guide and this document, this document shall prevail.

5.4. NUG Substation High Voltage Isolating Devices

Maintenance, safety, and system considerations require a visible break disconnect device to disconnect the NUG interconnection facilities from SaskPower's facilities. The disconnect device shall be connected on SaskPower's side of the NUG transformer, and on the line side of the metering transformers, when primary voltage metering is used. The device shall be accessible and lockable by SaskPower staff. The device must be accessible by SaskPower on a 24 hr basis without prior notice to the NUG Owner. Switches located inside locked facilities are not acceptable. Switches on NUG facilities where H_2S is present shall be located outside of the hazardous area.

Those customers engaging in self-generation who have purchased stand-by service from SaskPower may elect to provide a secondary voltage, visible break, isolating switch for their generator to avoid an outage to their load. This shall be in addition to the primary isolating switch. The switch shall be accessible and lockable by SaskPower staff. The switch must be accessible by SaskPower on a 24 hr basis without prior notice to the NUG Owner. Switches located inside locked facilities are not acceptable. Switches on NUG facilities where H_2S is present shall be located outside of the hazardous area.

5.5. NUG Substation High Voltage Fault Interrupting Device

The NUG facility shall be equipped with a high voltage device capable of isolating the transformer from SaskPower's distribution system in the event of a fault within the transformer or NUG

facilities. Fuses may be acceptable for applications using non synchronous generators; however, the NUG Owner should assess the risk of damage resulting from single phasing in the event of a single fuse failure. Non synchronous generator installations utilizing step-up transformers with a delta winding configuration on the utility side of the transformer must utilize a circuit breaker or similar three phase interrupting device to avoid ferroresonance. Where fused protection is used on the high side of the transformer, the NUG substation shall be equipped with a low voltage circuit breaker or contactor for tripping the generator.

NUG projects utilizing a synchronous generator shall be equipped with a three-phase circuit breaker on the high voltage side of the transformer.

The NUG Owner is responsible for insuring that the high voltage fault interrupting device coordinates with SaskPower's feeder protection. The NUG Owner shall submit proposed relay or fuse settings to SaskPower for review of protection coordination.

5.6. Transformer Requirements

5.6.1. Winding configuration For Non Synchronous Generators

SaskPower's requires that there be no zero sequence current contribution from induction generator based NUG facilities during faults on SaskPower's 25 kV system. The reason for this is that SaskPower does not want the presence or operation of the NUG facility to affect the coordination of its fused protection on single-phase taps with the main feeder protection. To achieve this objective, the NUG transformer connection must be:

- Delta on the 25 kV system with a grounded Wye on the low voltage side, or
- grounded Wye on the 25 kV system with a grounded or ungrounded Wye on the low voltage side. The grounded Wye connection on the low voltage side is only acceptable if the generator has a Delta or ungrounded Wye winding connection

5.6.2. Winding configuration For Synchronous Generators and Self-Commutating Inverters

The SaskPower electrical system is designed as an "effectively grounded" system. All NUG projects that utilize synchronous generators and self-commutating inverters must have a step-up transformer winding configuration that provides a ground current source which qualifies as 'effectively grounded'. Therefore, the interconnecting transformer must have:

- a solidly grounded wye connected high voltage winding with a delta connected secondary winding, or
- a delta connected high voltage winding with a separate grounding transformer connected to the high voltage terminals of the interconnecting transformer. In this circumstance the grounding transformer shall be connected directly to the interconnecting transformer terminals without an isolating device. The grounding transformer shall be in the same zone of protection as the interconnecting transformer.

To qualify as effectively grounded, the ratio of the zero sequence reactance to the positive sequence reactance $\frac{X_{zero}}{X_{positive}}$ as seen looking into the NUG facilities at the Point of Delivery from SaskPower's system (with the generator operating) shall be equal to or less than 3.0 and the ratio of the zero sequence resistance to the positive sequence reactance $\frac{R_{zero}}{X_{positive}}$ is not greater than one. For the purposes of calculating this ratio, the NUG Owner shall use the generator's direct axis transient reactance.

5.6.3. Transformer Rating

The transformer shall be sized to deliver rated kW and kVar. Rated kVar shall be based upon 0.98 power factor full load operation for induction generators and 0.9 power factor full load operation for synchronous generators.

The NUG Owner must take into consideration the presence of unbalanced loads on SaskPower's distribution system and size transformers with wye (SaskPower) – delta (NUG) windings to accommodate the continuous zero sequence currents that will flow in the transformer as a result of this load unbalance.

5.7. Metering Requirements

The metering will normally be located on the secondary side of the interconnecting transformer and compensated for losses to the Point-of-Delivery. Dual register, revenue approved metering capable of recording real and reactive power and energy delivery to and from the NUG facility separately will be required.

The NUG Owner shall provide any communication and interface facilities that SaskPower may require to the metering unit.

5.8. Required Protection

The NUG generator shall be equipped with the protection set out in Sections 5.8.1 through 5.8.4. The NUG Owner shall submit proposed settings for all required protection to SaskPower for review of protection coordination. In the following sections, the term 'relay' is used in a general sense. It is recognized that some NUG technologies may utilize packaged protection systems that integrate the protection functions into one device, rather than utilizing individual 'relays'.

5.8.1. Over current Protection

All NUG projects shall be equipped with over current protection to trip the generator off in the event of a fault on SaskPower's system or a fault within the generator. Some NUG installations may require the application of more sophisticated protection schemes such as distance type protection in order to achieve coordination with SaskPower's protection systems. Voltage restrained over current protection (51V) may facilitate better coordination with SaskPower's protection systems.

5.8.2. Over and Under Frequency Protection

All NUG projects shall have under and over frequency protection relays that will disconnect the generator from SaskPower's system if the frequency deviates from 60Hz. The normal trip settings are frequencies of 59.5 Hz and 60.5 Hz sustained for more than 0.5 seconds.

5.8.3. Over and Under Voltage Protection

All NUG projects shall have under and over-voltage protection relays which will disconnect the generator from SaskPower's system in the event of abnormal voltages. The under-voltage trip setting shall be adjustable over a range of 85% to 100% of nominal. The over-voltage trip setting shall be adjustable over a range of 105% to 115% of nominal. The under voltage and over voltage protection shall have adjustable time delays. The time delay shall be independently adjustable for the over and under voltage trip settings. It may be advantageous to provide a separate instantaneous or very high speed over voltage protection for the detection of self excitation or ferroresonance conditions.

5.8.4. Power Flow Relay

NUG owners who are generating to displace load, but do not have a Service And Supply Agreement covering the provision of standby service from SaskPower, shall have a power

flow relay which isolates the load and generation from SaskPower's system in the event of power flow into the customer's facility. A time delay of up to 5 seconds on this relay is permissible to minimize nuisance trips.

5.9. Additional Protection

The NUG Owner is responsible to evaluate the requirement for protection schemes to be applied to the generator. In addition to the required protection set out in Section5.8, it is recommended that the NUG Owner evaluate the requirement for the following protection schemes:

5.9.1. No-volts Auto Reclose Protection

SaskPower applies auto reclose to its primary distribution system. If the NUG generator cannot withstand the reacceleration that will occur following reclose, it is recommended that the NUG generator be equipped with a no-volts relay that trips the NUG generator off during the reclose dead time.

5.9.2. Unbalance Relay

It is recommended that an unbalance or negative sequence relay be installed that trips the NUG generator on excessive current unbalance. This is particularly important if fused protection is used on the primary of the NUG transformer.

5.9.3. Broken Delta Protection (59G)

A grounded wye (primary) – broken delta (secondary) voltage transformer with a 59G over voltage relay connected across the terminals of the broken delta can facilitate detection of ground faults.

5.9.4. Rate-of-Change of Frequency Relay

The application of a rate-of-change of frequency relay may be a suitable means of detecting a power island condition. The NUG Owner shall submit proposed settings to SaskPower for review.

In the preceding sections, the term 'relay' is used in a general sense. It is recognized that some NUG technologies may utilize packaged protection systems that integrate the protection functions into one device, rather than utilizing individual 'relays'.

5.10. Auto Resynchronization

For NUG projects which have an installed capacity in excess of 100 kW, the acceptability of the auto start up and resynchronization of generators following the trip of the feeder to which the NUG generator is connected will be assessed by SaskPower on a case by case basis. If permitted, the NUG generator must be equipped with a relay that senses the presence of normal voltage for a period of time, typically five minutes. Normal voltage is defined as being within 94% to 106% of nominal. The time period must be adjustable between 1-60 minutes and will be determined by SaskPower. If multiple NUG generators exist on any one distribution feeder, SaskPower reserves the right to stagger generator automatic restart times.

5.11. Induction Generator and Inverter Requirements

The following requirements apply to induction generators and non self commutating inverters. Self commutating inverters should be treated as synchronous generators.

5.11.1. Voltage Deviations

SaskPower sets requirements in terms of limiting the voltage sags, swells, and flicker caused by the operation of customer equipment. The NUG Owner must design the equipment and control its operation to ensure that it does not exceed these limits.

Induction generators and inverters are unable to generate power before they are connected to the utility system and therefore, there is no real synchronization required. The induction generator may be used as a motor to accelerate the prime mover to operational speed. If the NUG generator is to be brought up to speed using across the line starting from SaskPower's system, the maximum voltage sag during starting at the Point of Delivery must be limited to 8% or less. This is assuming that the generator is started less frequently than once per day. For more frequent starts refer to the voltage flicker limits set out in Section 1.2.10 b) of SaskPower's Electric Service Guide. As an alternative to across the line starting, the NUG generator may be closed onto the SaskPower system after it has been brought up to near synchronous speed using the prime mover. The voltage deviation that results from the connection of the generator to SaskPower's system using this starting technique must also meet the preceding limits.

The voltage sag that results from the tripping of the NUG generator from SaskPower's system must be limited to 8% or less at the PCC. This is assuming that the generator trips less frequently than once per day. If more frequent trips are anticipated, or actual experience indicates that trips are more frequent, the acceptable voltage deviation will be defined by the voltage flicker limits in SaskPower's Electric Service Guide. To minimize disturbances to other customers, SaskPower requires that for planned shutdown (not initiated by a protection system) of the NUG generator, the output of the NUG generator should be reduced to zero before the NUG generator is disconnected from SaskPower's system.

5.11.2. Voltage Control \ Power Factor Control Requirements

For the purposes of clarification, leading power factor operation of a generator means that the generator is drawing reactive power off of the distribution system.

Voltage regulation on distribution circuits is required in order to maintain the service supply voltage for end-use customers within acceptable limits. Uncompensated induction generators and inverters are seen by the distribution system as a reactive power load, which affects voltage control on the distribution system. Unless SaskPower indicates otherwise, induction generators and inverters must be equipped with power factor correction equipment to be installed at the NUG Owner's expense.

A NUG facility using an induction generator or inverter must normally be equipped with sufficient power factor correction capacitors to correct the full load power factor to at least 0.97 leading. The power factor correction capacitors must normally be provided in steps to follow the output of the generator. Sufficient steps shall be provided to maintain the power factor of the generator between 0.97 leading and 1.00 over the expected power output range. The power factor at very low generator outputs (less than 5% of rated output) may drop below 0.97 leading. The capacitor switched in at start up shall be sized to meet the voltage deviation requirements set out in Section 5.11.1 of this document.

The power factor controller shall have a voltage override that causes it to switch out capacitors if the voltage at the Point Of Delivery exceeds an upper limit to be specified by SaskPower. The normal upper limit is 105% of nominal; however, the power factor control equipment shall have provision to adjust this upper limit between 100 and 110% of nominal. The NUG power factor control equipment shall also have provision for a time delay between sensing an excursion of the upper voltage and initiating control action. The power factor control equipment shall have provision to allow for the adjustment of this time delay between 0 and 180 seconds. SaskPower will specify the required time delay.

5.11.3. Power Island Operation via Self Excitation of the Generator

Self-excitation of an induction generator is a condition where there is sufficient capacitance connected to the terminals of the generator to provide excitation current to the generator which will maintain a voltage on its terminals after it has been isolated from the power system. This exciting current can be provided by local power factor correction capacitors or, if the generator is isolated along with a portion of SaskPower's distribution system (a power island), the feeder line capacitance and any capacitors on SaskPower's system.

The NUG Owner must ensure that their facility will not sustain a power island through self-excitation of their generator. Aside from the danger to SaskPower staff of an unexpected power island, the voltages that occur in a power island resulting from self-excitation are uncontrolled, and may result in apparatus damage.

Local protection schemes at the NUG facility may be acceptable for the detection of, and subsequent isolation from power island conditions.

Unless the NUG Owner can demonstrate through the execution of analytical studies, that there is no risk of self-excitation of the generator, the NUG Owner must demonstrate, to SaskPower's satisfaction:

- that the NUG protection systems are capable of detecting a power island condition,
- that in the event self-excitation in a power island condition, isolation of the NUG will occur quickly enough to preclude damage to other customers or SaskPower's system from the abnormal voltages that may occur, and
- that the interrupting device used to separate the NUG generator from SaskPower's power system is capable of operating at the elevated voltages which may occur following self-excitation,

Failure to meet the preceding requirements may mean that the NUG Owner is responsible for the cost of installing special protection schemes. This may include a direct trip signal from SaskPower's source substation to the NUG Owner's facility or other generation facilities on the feeder whenever there is a trip on the feeder to which the NUG is connected.

In assessing the opportunity for a self-excited power island, the total amount of capacitance on the feeder to which the NUG is connected must be taken into consideration. This includes power factor correction capacitors at the NUG site, discrete capacitors on the feeder, and the distributed capacitance of the feeder itself. The assessment must also take into consideration the presence of existing generators on the same feeder along with the minimum load likely to be connected to the feeder. SaskPower will provide information on load, feeder characteristics, and the location of capacitors on its system to facilitate assessment of the risk of self-excitation. Such details are site specific.

5.12. Synchronous Generator Requirements

5.12.1. Synchronizing Facilities

The NUG facility is required to have facilities to facilitate synchronization of its units to the SaskPower system. These facilities will typically consist of a synchronizing relay and a sync check relay. The settings on these relays must be submitted to SaskPower for review to insure that they will not adversely affect the operation of SaskPower's system. The NUG operator is responsible for synchronizing its generator to SaskPower's system following instructions as set out in the operating agreement.

5.12.2. Voltage Regulation Requirements

For the purposes of clarification, leading power factor operation of a generator means that the generator is drawing reactive power off of the distribution system.

SaskPower requires that the NUG generator shall be capable of operating continuously with a terminal voltage between 95 and 105 percent of the rated generator voltage. Synchronous machines shall be capable of delivering rated output power at a power factor of +0.9 (lagging) or -0.95 (leading).

Synchronous machines shall be equipped with a voltage regulator and exciter with the capability to control the terminal voltage of the generator continuously between 80% and the upper limit of the rated voltage of the generator from no-load to full-load. SaskPower shall determine the actual set point. The regulator shall be capable of controlling the generator terminal voltage to within 0.5% of the set point without hunting.

In order to coordinate with its existing voltage control devices, SaskPower may require that synchronous generators operate in a power factor control mode. The voltage / power factor regulator shall be capable of controlling the power factor of the generator between +0.95 and -0.95 from no-load too full-load. SaskPower shall determine the actual set point. The regulator shall be capable of controlling the power factor to within 0.5% of the set point without hunting.

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

The excitation system shall not trip, and shall continue to operate during faults on SaskPower's distribution system, and shall recover and return to normal operation immediately following the fault. Controls should continue to operate down to generator terminal voltages approaching 20% of rated voltage, and shall continue to operate during the extremely unbalanced voltage conditions that could occur during fault conditions on SaskPower's distribution system.

5.12.3. Self-Excitation

Self-excitation of a synchronous generator can occur if the generator plus a portion of the SaskPower system, becomes isolated from the rest of SaskPower's system, resulting in a power island. In a power island condition, self-excitation of the generator will take place if the reactive load on the generator resulting from line capacitance or capacitors on SaskPower's system, exceeds the capability of the generator and its excitation / voltage regulator system to control the voltage. The voltage rise following the onset of self-excitation in a synchronous machine can be very rapid and may only be limited by saturation effects. Self-excitation is exacerbated by the over-frequency that may follow a partial loss of load. The over-voltages resulting from self-excitation can be very high and may result in apparatus damage.

Unless the NUG Owner can demonstrate through the execution of analytical studies, that there is no risk of self-excitation of the generator, the NUG Owner must demonstrate, to SaskPower's satisfaction:

- that the NUG facility has protection systems to detect a self-excitation condition,
- that the interrupting device provided by the NUG Owner is be capable of switching the anticipated leading power factor current at the anticipated elevated voltages, and
- that isolation of the NUG will occur quickly enough to preclude damage to other customers or SaskPower's system from the abnormal voltages that may occur.

Failure to meet the preceding requirements may mean that the NUG Owner is responsible for the cost of installing special protection schemes. This may include a direct trip signal from SaskPower's source substation to the NUG Owner's facility or other generation facilities on the feeder whenever there is a trip on the feeder to which the NUG is connected.

In assessing the risk of self-excitation, the total amount of capacitance on the feeder to which the NUG is connected must be taken into consideration. This includes discrete capacitors on the feeder, and the distributed capacitance of the feeder itself. The assessment must also take into consideration the presence of existing generators on the same feeder along with the minimum load likely to be connected to the feeder. SaskPower will provide information on load, feeder characteristics, and the location of capacitors on its system to facilitate assessment of the risk of self-excitation. Such details are site specific.

5.12.4. Power Island Operation

Operation of a NUG synchronous generator connected with SaskPower load in a power island is not permitted. Unless the NUG Owner can demonstrate through the execution of analytical studies, that there is no risk of creating a power island, the NUG Owner must demonstrate, to SaskPower's satisfaction that the NUG protection systems are capable of detecting a power island condition (note that a power island condition may or may not be accompanied by self-excitation of the generator). Failure to meet the preceding requirements may mean that the NUG Owner is responsible for the cost of installing special protection schemes. This may include a direct trip signal from SaskPower's source substation to the NUG Owner's facility or other generation facilities on the feeder whenever there is a trip on the feeder to which the NUG is connected.

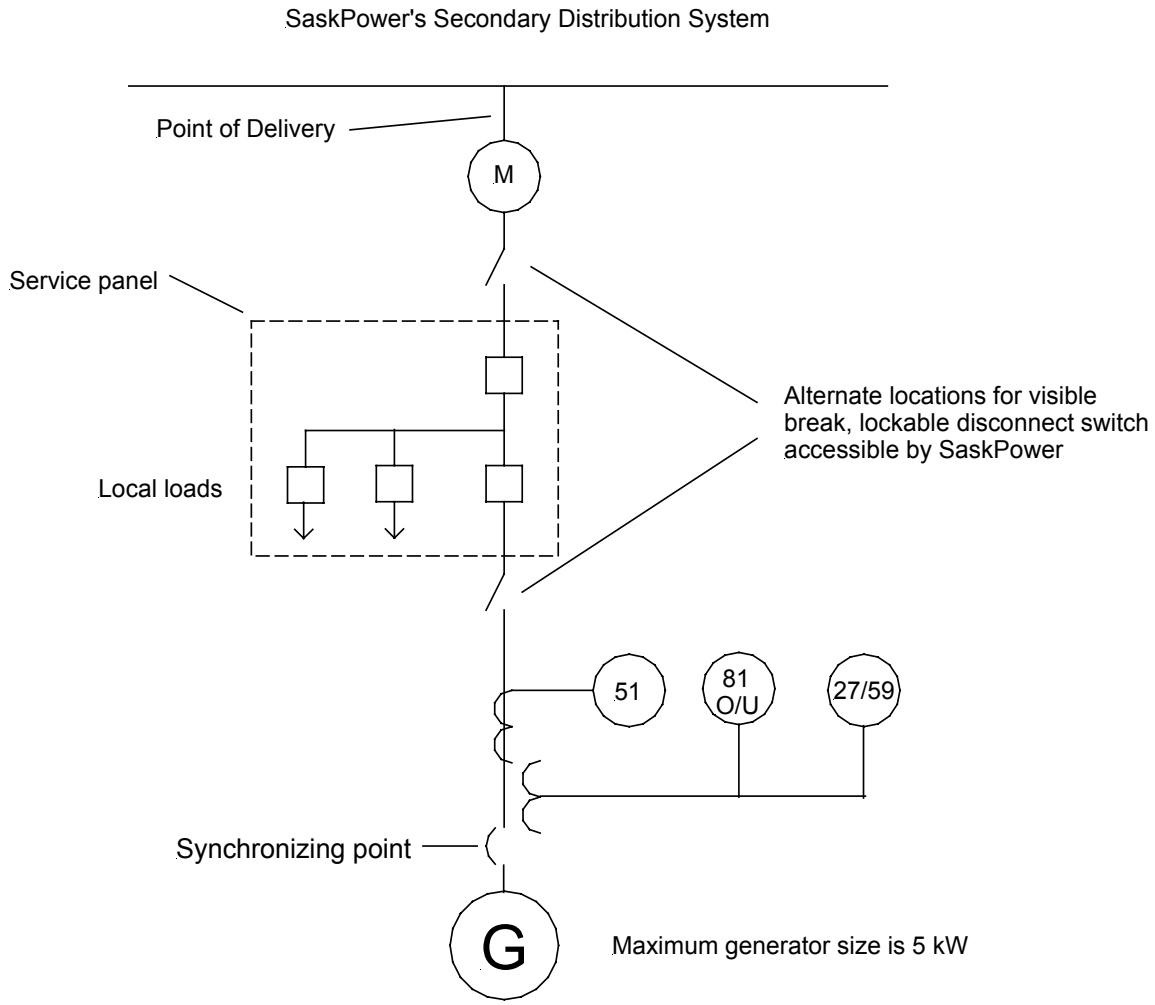
5.12.5. Synchronous Compensator Operation

Synchronous compensator operation is not required for synchronous generators connected to the distribution system.

5.12.6. Governor Operation and Frequency Control

All synchronous generators shall be required to have speed governors on their prime movers. Synchronous generators that are 1000 kW or less in size and are connected to SaskPower's distribution system are not required to contribute to frequency control on the SaskPower system.

APPENDIX A:
Typical Arrangements

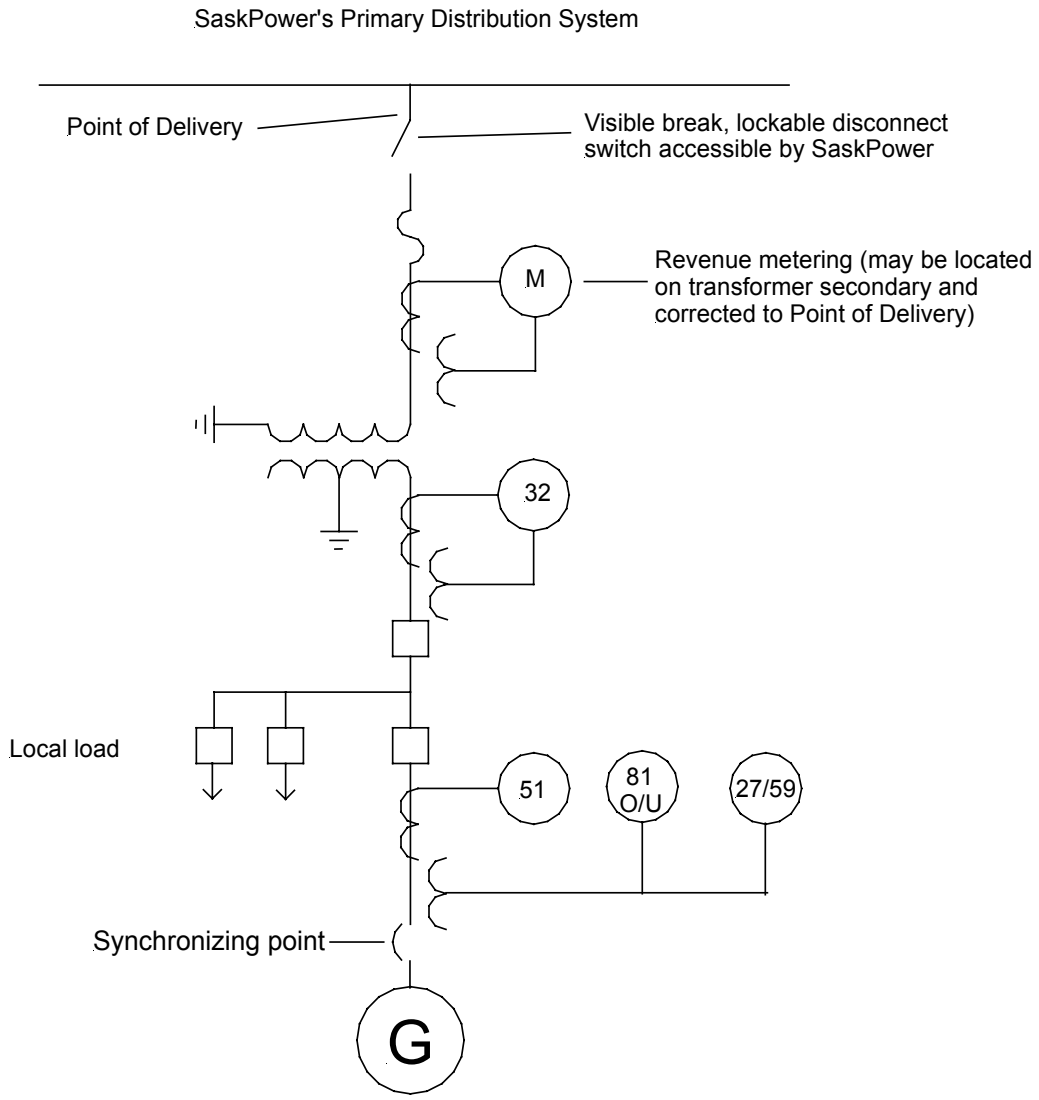


Protection Functions:

51	Overcurrent protection
81O/U	Over / under frequency protection
27/59	Under / over voltage protection
M	Revenue metering

Note: Typical requirements shown. NUG owner shall evaluate requirements for further protection

FIGURE #1
TYPICAL SINGLE PHASE GENERATOR INSTALLATION CONNECTED TO SASKPOWER'S SECONDARY DISTRIBUTION SYSTEM

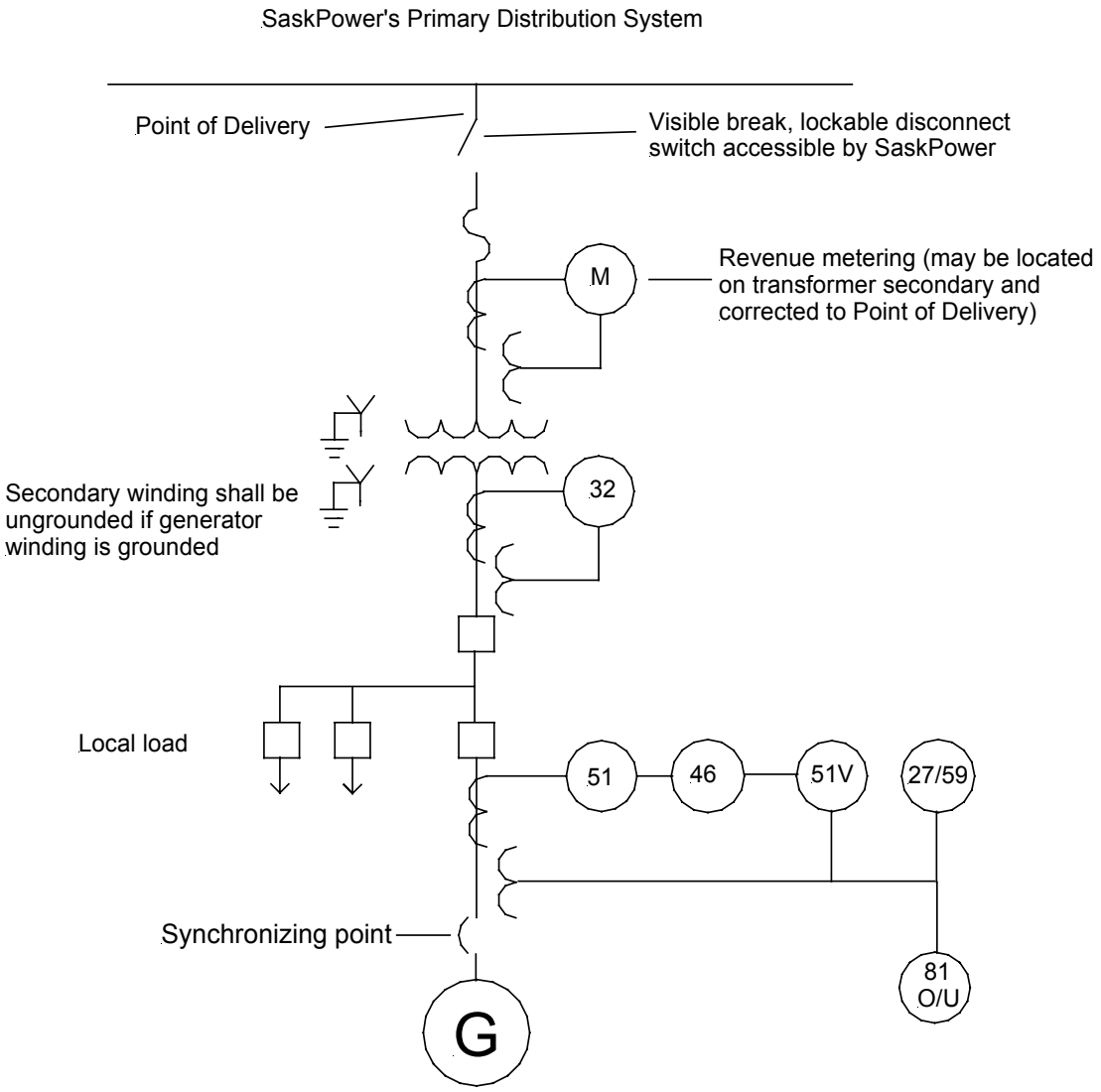


Protection Functions:

51	Overcurrent protection
32	Reverse power protection (required if customer does not purchase stand-by)
81O/U	Over / under frequency protection
27/59	Under / over voltage protection
M	Revenue metering

Note: Typical requirements shown. NUG owner shall evaluate requirements for further protection

FIGURE #2
TYPICAL SINGLE PHASE NON SYNCHRONOUS GENERATOR INSTALLATION UP TO 100 KW

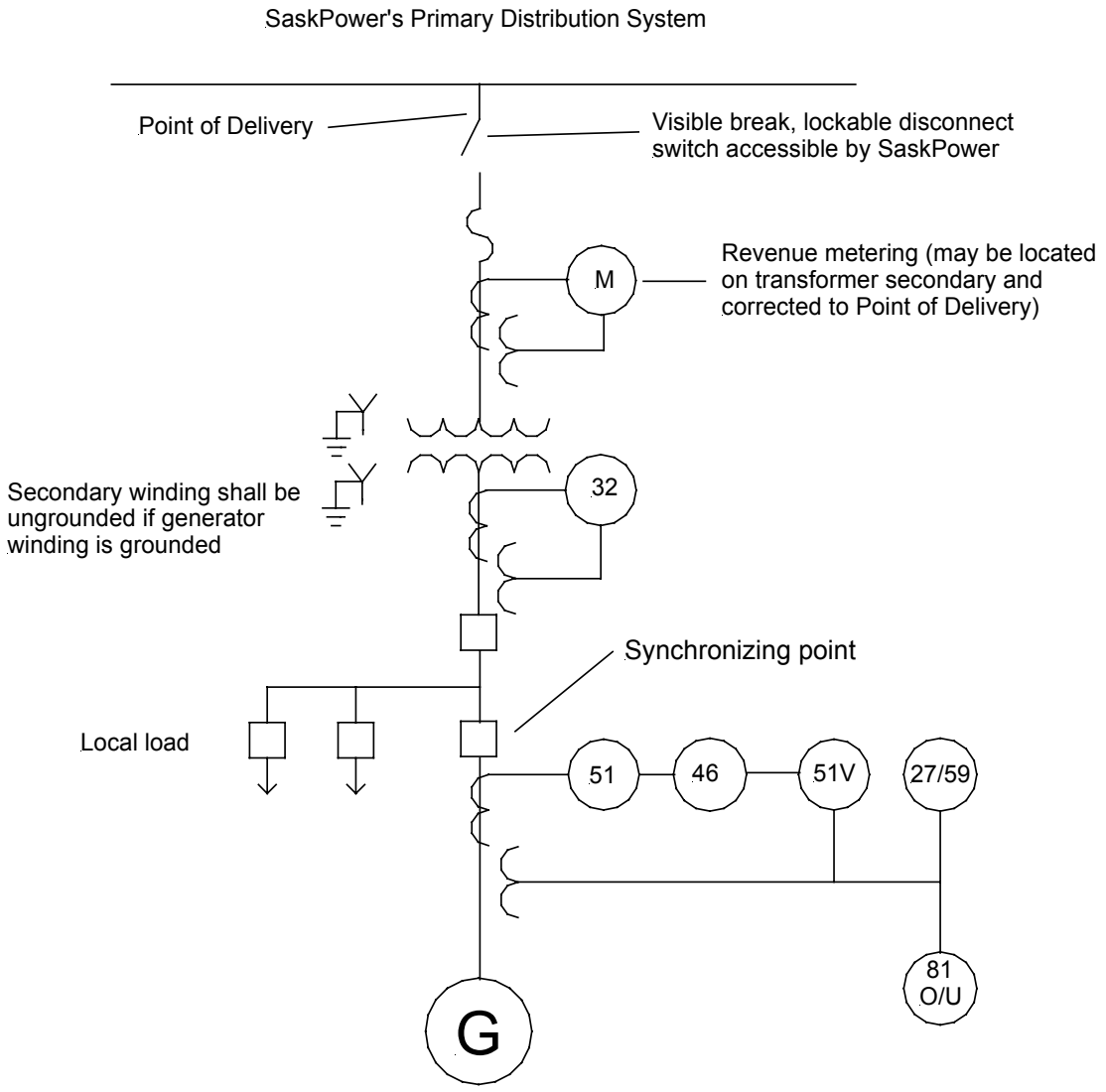


Protection Functions:

51	Overcurrent protection
51V	Voltage restrained overcurrent protection
32	Reverse power protection (required if customer does not purchase stand-by)
81O/U	Over / under frequency protection
27/59	Under / over voltage protection
46	Phase unbalance protection
M	Revenue metering

Note: Typical requirements shown. NUG owner shall evaluate requirements for further protection

FIGURE #3
TYPICAL THREE PHASE NON SYNCHRONOUS GENERATOR INSTALLATION UP TO 100 KW

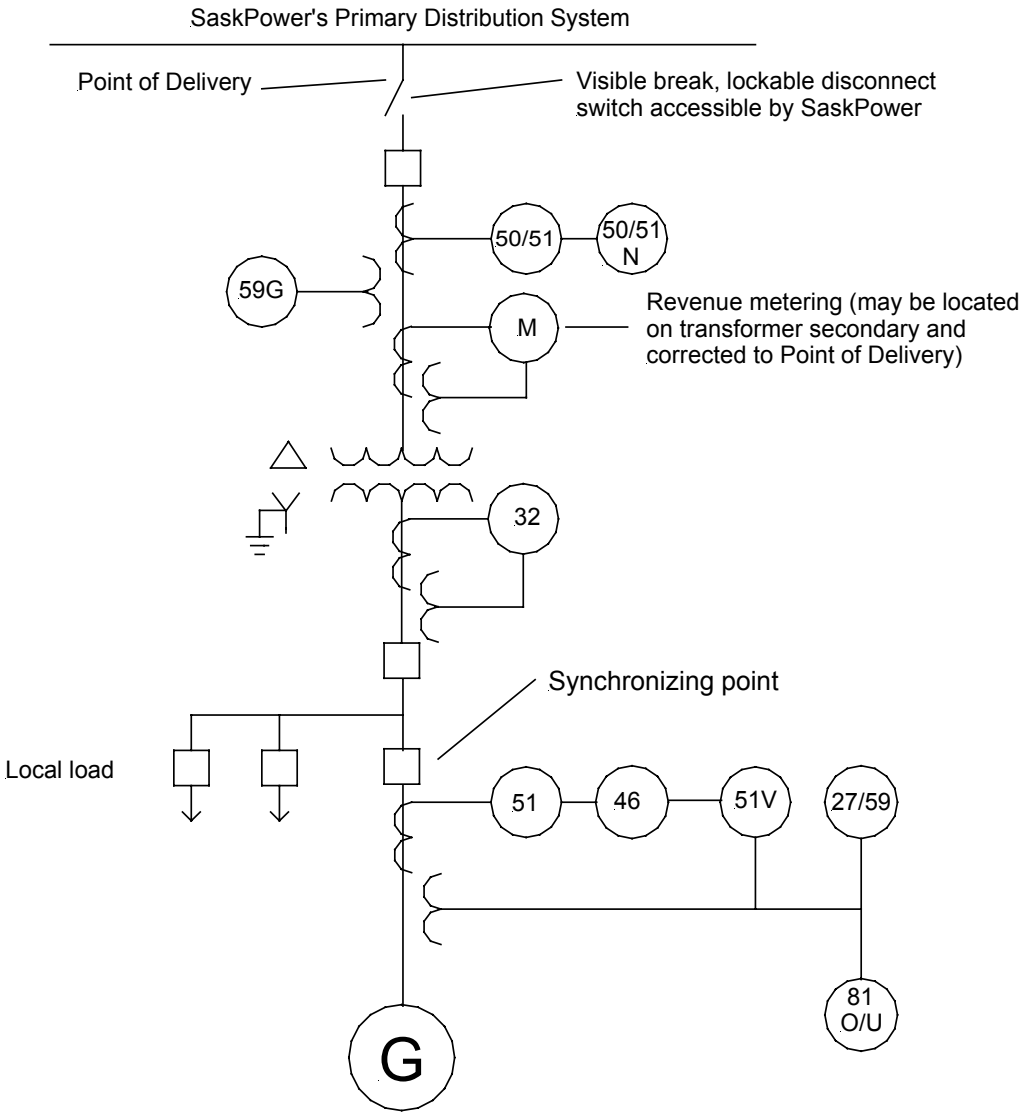


Protection Functions:

51	Overcurrent protection
51V	Voltage restrained overcurrent protection
32	Reverse power protection (required if customer does not purchase stand-by)
81O/U	Over / under frequency protection
27/59	Under / over voltage protection
46	Phase unbalance protection
M	Revenue metering

Note: Typical requirements shown. NUG owner shall evaluate requirements for further protection

FIGURE #4
TYPICAL THREE PHASE NON SYNCHRONOUS GENERATOR INSTALLATION, 100 TO 1000 KW WITH GROUNDED WYE TRANSFORMER PRIMARY WINDING

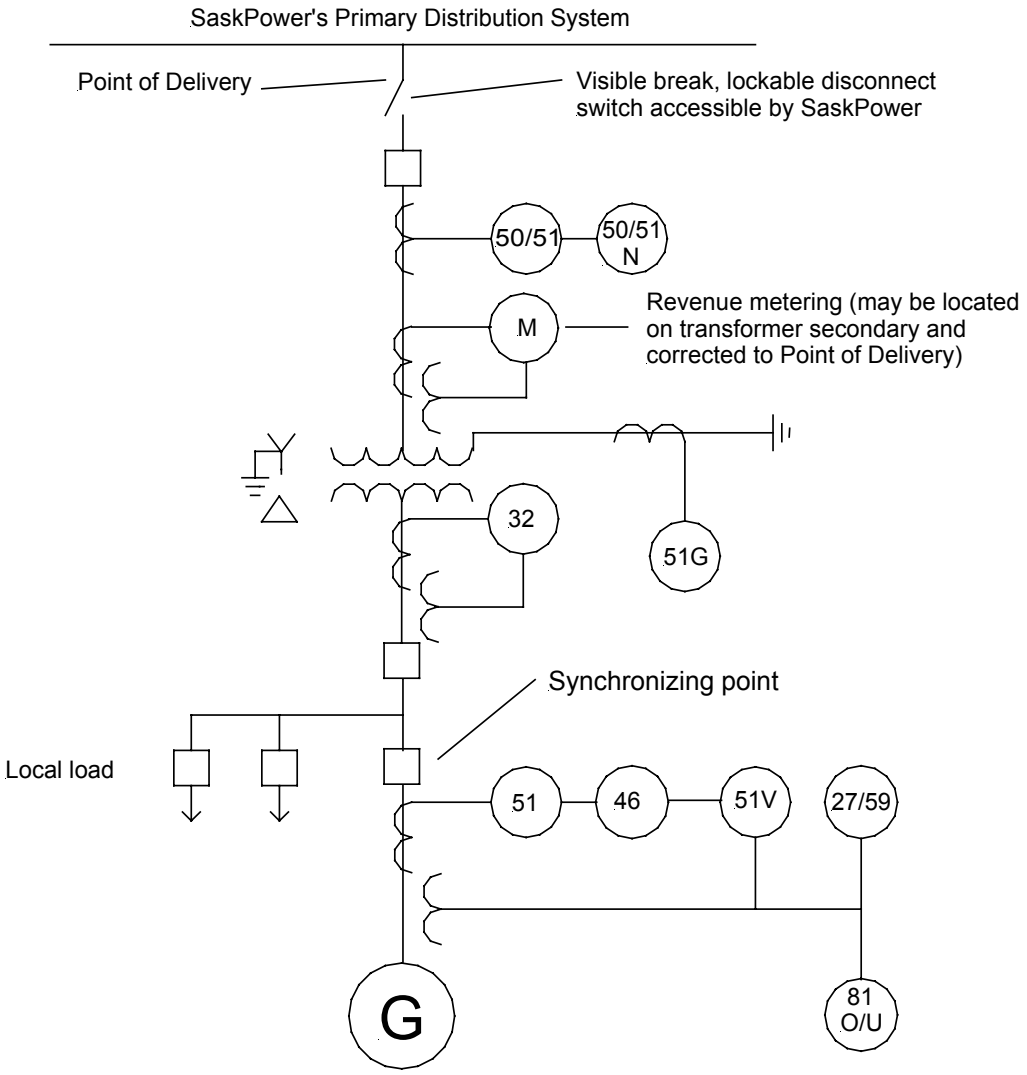


Protection Functions:

50/51	Overcurrent protection
51V	Voltage restrained overcurrent protection
59G	Broken delta overvoltage protection
32	Reverse power protection (required if customer does not purchase stand-by)
81O/U	Over / under frequency protection
27/59	Under / over voltage protection
46	Phase unbalance protection
M	Revenue metering

Note: Typical requirements shown. NUG owner shall evaluate requirements for further protection

FIGURE #5
TYPICAL THREE PHASE NON SYNCHRONOUS GENERATOR INSTALLATION, 100 TO 1000 KW WITH DELTA TRANSFORMER PRIMARY WINDING



Protection Functions:

50/51	Overcurrent protection
51V	Voltage restrained overcurrent protection
51G	Ground overcurrent protection
32	Reverse power protection (required if customer does not purchase stand-by)
81O/U	Over / under frequency protection
27/59	Under / over voltage protection
46	Phase unbalance protection
M	Revenue metering

Note: Typical requirements shown. NUG owner shall evaluate requirements for further protection

FIGURE #6
TYPICAL SYNCHRONOUS GENERATOR INSTALLATION (ALL SIZES)

SaskPower

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APPENDIX B:

REQUEST FOR PRELIMINARY INTEGRATION STUDY

To: Senior Engineer, Independent Power Producer Options
Customer Services Business Unit
SaskPower
2025 Victoria Avenue
Regina, Saskatchewan
S4P 0S1

PROPONENT		
Company Name:		
Mailing Address:	Street	
	City	
	Province / State	
	Country	
	Postal Code	
CONTACT PERSON		
Name & Title		
Mailing Address	Street	
	City	
	Province / State	
	Country	
	Postal Code	
Telephone Number:		
Fax		
Email		
SITE LOCATION AND IN-SERVICE DATE		
Land Location & Legal Description		
Proposed In-Service Date:		

GENERATOR DATA		
Type (synchronous, etc.):		
Rating of generators (kV.A)		
Number of generators:		
Power factor at rated output (%):		
Annual energy production from site (MW.hr)		
Production capacity range	Maximum (kW)	
	Minimum (kW)	
TRANSFORMER DATA (if available)		
Rating ONAN/ONAF (kV.A):		
Winding connections:	HV winding	
	LV winding	
Positive sequence impedance: (% on ONAN base)		
Zero sequence impedance: (% on ONAN base)		
DRAWINGS		
General site location map showing location of NUG Facility		
Preliminary substation layout drawing		
Preliminary protection and metering single line		
SIGNATURES		
Submitted by:		
Date:		
FOR SASKPOWER USE ONLY		
Received by:		
Date and time:		

SaskPower

REV 2000 OCT 17

APPENDIX C:

REQUEST FOR FORMAL INTEGRATION STUDY

To: Senior Engineer, Independent Power Producer Options
Customer Services Business Unit
SaskPower
2025 Victoria Avenue
Regina, Saskatchewan
S4P 0S1

PROPONENT		
Company Name:		
Mailing Address:	Street	
	City	
	Province / State	
	Country	
	Postal Code	
CONTACT PERSON		
Name & Title		
Mailing Address	Street	
	City	
	Province / State	
	Country	
	Postal Code	
Telephone Number:		
Fax		
Email		
SITE LOCATION AND IN-SERVICE DATE		
Land Location & Legal Description		
Proposed In-Service Date:		
ENERGY PRODUCTION		
Expected energy production from site for each month of the year (MW.hr)		

GENERATOR DATA		
Type (synchronous, etc.):		
Number of generators:		
Data Required for Synchronous Machines (impedances expressed in per unit on machine base)	Rating of generator (kV.A)	
	Power factor at rated output (%)	
	Speed (RPM)	
	Inertia constant (H) (Generator and prime mover)	
	Direct axis synchronous reactance (x_d)	
	Direct axis transient reactance (x'_d)	
	Direct axis subtransient reactance (x''_d)	
	Quadrature axis synchronous reactance (x_q)	
	Quadrature axis transient reactance (x'_q)	
	Quadrature axis subtransient reactance (x''_q)	
	Open circuit direct axis transient time constant (T'_{do})	
	Short circuit direct axis transient time constant (T'_d)	
	Open circuit direct axis subtransient time constant (T''_{do})	
	Short circuit direct axis subtransient time constant (T''_d):	
	Quadrature axis transient time constant (T'_{qo})	
	Quadrature axis subtransient time constant (T''_{qo})	
	Armature Resistance (R_a)	
	Stator leakage reactance (X_l)	
	Armature short circuit time constant (T_a)	
	Saturation factor at 1.0 per-unit flux	

GENERATOR DATA (Cont'd)			
Data Required for Synchronous Machines (impedances expressed in per unit on machine base)	Saturation factor at 1.2 per-unit flux		
	Negative sequence resistance (R_2)		
	Negative sequence reactance (X_2)		
	Zero sequence resistance (R_0)		
	Zero sequence reactance (X_0)		
Data Required for Induction Machines (impedances expressed in per unit on machine base)	Rating (kV.A)		
	Rated Power factor (%)		
	Speed (RPM):		
	Inertia constant (H) (Generator and prime mover)		
	Stator resistance (R_s)		
	Stator Reactance (X_s)		
	Rotor resistance (R_r):		
	Rotor reactance (X_r)		
	Armature magnetizing reactance (X_m)		
VOLTAGE / POWER FACTOR CONTROL			
Power factor or voltage regulator control range		To	
Power factor or voltage regulator setting tolerance			
For synchronous generators provide:	A description of the excitation system (rotating brushless, static, etc)		
	An AVR / Exciter Laplace-domain control block diagram showing all control blocks with all time constants greater than 0.02s, completely specifying the transfer function from the generator terminal voltage, and field current, to the generator field voltage.		
For induction generators or inverters provide:	A description of the proposed voltage / power factor control system		

HARMONICS		
	For generators connected to SaskPower's system through an inverter(s), provide the expected worst case harmonic current injection (in amperes for all individual harmonics) back into the SaskPower system for all harmonics up to the 35th order.	
GOVERNOR CONTROLS		
For synchronous generators provide	A description of the proposed governor system:	
	A Laplace-domain control block diagram showing all control blocks with all time constants greater than 0.02s, completely specifying the transfer function for the prime mover / governor system.	
For other generators provide	A description of the proposed power control system	
For sites with fluctuations in prime mover output (wind power, etc) provide:	A description of expected, and maximum frequency and magnitude variations in power output	
	Rate at which unit output can increase or decrease	
Production capacity range	Maximum (kW)	
	Minimum (kW)	
TRANSFORMER DATA (if available)		
Rating ONAN/ONAF (kV.A):		
Winding voltage and connections	HV winding	
	LV winding	
Positive sequence impedance: (% on ONAN base)		
Zero sequence impedance: (% on ONAN base)		
On-load tap range (if provided)		
On-load tap size		
Off-load tap range		
Off load tap size		

SUBSTATION	
Type of primary interrupting device (circuit breaker, fuses, etc)	
Interrupting rating (amperes)	
Operating speed (cycles)	
DRAWINGS	
General site location map showing location of NUG Facility	
Preliminary substation layout drawing	
Preliminary protection and metering single line	
SIGNATURES	
Submitted by:	
Date:	
FOR SASKPOWER USE ONLY	
Received by:	
Date and time:	

APPENDIX D: OPERATING AGREEMENT

In addition to the Service And Supply Agreement or Interconnection Agreement for Small Generators , the proponent will be required to negotiate and sign an agreement covering standard operating practices. Specific items to be addressed within the agreement will include but are not limited to the following:

- Definition of maintenance and operating interface devices.
- Establish NUG “lock out” procedures.
- Establish communication procedures for normal contact and emergency contact.
- Identification of safety procedures, protective equipment requirements, or other procedures for SaskPower staff entering the NUG Facilities
- Alarm and fault reporting procedures;
- Protection settings, including procedures for making changes and verification of changes;
- Voltage scheduling and control;
- Restoration procedures (synchronization)
- Initial synchronization.
- Initial synchronization following maintenance.
- Synchronization following disconnection due to:
- Fault on SaskPower system,
- Fault on NUG system,
- System request,

TERMS AND DEFINITIONS

ANSI	American National Standards Institute or any successor organization or assigns.
AVR	Automatic Voltage Regulator
CEA	Canadian Electrical Association
CSA	Canadian Standards Association or any successor organization or assigns.
Effectively Grounded System	AIEE Standard No. 32-1.05, May 1947, defines effective grounding as follows: A system or portion of a system can be said to be effectively grounded when for all points on the system or specified portion thereof the ratio of zero-sequence reactance to positive-sequence reactance is not greater than three and the ratio of zero-sequence resistance to positive-sequence reactance is not greater than one for any condition of operation and for any amount of generator capacity. (Reference "Electrical Transmission and Distribution Reference Book," Westinghouse Electric Corporation, USA, 1964.)
Generation	Generation means any device which produces electrical energy including devices which release stored electrical energy (storage means stored for greater than 16 ms). Parallel or synchronous operation means operation of any generator whose output terminals are connected directly or through any intermediary facilities to SaskPower's transmission system.
GCC	Grid Control Centre
Integration Studies	Studies carried out by SaskPower is to identify the interconnection facilities that have to be added to SaskPower's system to accommodate the proposed NUG project along with their cost. The studies also assess whether the proposal by the NUG proponent meets SaskPower's technical requirements for interconnection.
Interconnection Agreement for Small Generators	An agreement, for generation projects up to 100 kW, between SaskPower and the NUG Owner covering the technical requirements for interconnection of the NUG Facilities with SaskPower's system and the sale of energy to or the purchase of energy and other services from SaskPower.
Interconnection Facilities	This includes but is not limited to: ■ Electric power lines required to connect the NUG to the SaskPower transmission system. ■ Apparatus at both the NUG and SaskPower substations including current transformers (CTs), potential transformers (PTs), high voltage isolating switch complete with visible break and suitable for locking, a

	high-voltage fault interrupting device, and ground switch suitable for locking. ■ Generator step-up transformer complete with on-load tap changer. ■ Communications, protection and control facilities. ■ Metering equipment. ■ Special protection systems.
NEMA	National Electrical Manufacturers Association or any successor organization or assigns.
Non-Utility Generation or NUG	Generation connected to the SaskPower transmission system which is not exclusively owned by SaskPower. This includes: ■ Co-Generation - the simultaneous generation in one plant of electricity and useful thermal or mechanical energy. ■ Independent Power Production (IPP) - investor-owned facilities dedicated exclusively to the generation of electrical energy. ■ Self-Generation – customer-owned generation which is used to supply load at the customer site. This may include energy produced from on-site co-generation facilities.
NUG Facilities	Non-utility generation facilities consist of the generating equipment; the substation, complete with transformer; and all associated equipment at the site.
Service And Supply Agreement	An agreement, for generation projects in excess of 100 kW, between SaskPower and the NUG Owner covering the technical requirements for interconnection of the NUG Facilities with SaskPower's system and the sale of energy to, or the purchase of energy and other services from SaskPower.
NUG Owner	The owner of the non-utility generation facilities.

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