



NON-UTILITY GENERATION
INTERCONNECTION REQUIREMENTS
AT VOLTAGES 72 kV AND ABOVE

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Non-Utility Generation Interconnection Requirements at Voltages 72 kV and Above

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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 and operates synchronously with the SaskPower Bulk Electric System (BES).
- Does not constitute a design handbook. Non-Utility Generation (NUG) Owners who are considering the development of a generation facility intended for connection to the SaskPower Transmission System should engage the services of qualified individuals.

1.2. Purpose

The purpose of the interconnection requirements document is to facilitate the process associated with connecting NUG to the SaskPower system. Specifically, the information provided should allow potential generation owners to conduct project feasibility assessments, which can include the costs associated with these technical requirements for connection.

This document contains information pertaining to the SaskPower Transmission System characteristics, operating practices and procedures, 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 non-utility generation to the SaskPower Transmission 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.

1.3. Scope

The interconnection requirements apply to synchronous type generation that is not exclusively owned by SaskPower and is connected to and operates in synchronism with the SaskPower BES.

Induction or other types of power generators are not included within the scope of this document. However, these other types of generators will be addressed separately on a case-by-case basis.

The interconnection requirements are intended to cover three-phase installations connected to the SaskPower Transmission System at 72 kV and above.

The use of the terms "Transmission System" and "Bulk Electric 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 does NOT cover the interconnection to distribution level voltages (25 kV and below). For interconnection to the distribution system, refer to "Non-Utility Generation Interconnection Requirements at Voltages 25kV and Below".

1.4. Ownership and Payment for Facilities

SaskPower will own, maintain and operate all facilities on the system 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 3.12 and 3.13**. The aforementioned change in division of 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 Transmission System. The NUG Owner is also responsible for the costs of future changes to the NUG Facilities.

1.5. Agreements, Approvals, Permits and Compliance Standards

Agreements:

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

- (a) Sign a Power Purchase Agreement (“PPA”) with SaskPower in order to sell energy to SaskPower;
- (b) Sign an interconnection agreement with SaskPower in order to connect generation facilities to the SaskPower Transmission System and acquire any required Interconnected Operations Service (IOS);
- (c) Sign an Operating Agreement with SaskPower, which agreement shall outline standard operating practices. Please refer to Appendix “C” for a detailed outline of the requirements of the Operating Agreement; AND
- (d) Attend a Grid Operations Meeting (GOM) upon notice from SaskPower for the purpose of establishing procedures and permits for the initial electrical connection between the NUG Facilities and the SaskPower Transmission System.

Approvals and Permits:

The NUG Owner shall be responsible for determining requirements and obtaining any licenses, permits or approvals necessary to ensure compliance with any applicable 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.

Compliance Standards:

NUG Facilities operating in synchronism with the SaskPower BES shall comply with all NERC Planning Standards and Operating Policies pertaining to transmission facilities and generation owners. In addition, any specific requirements of SaskPower or the applicable Regional Reliability Organization (RRO), with which SaskPower has an agreement, must be met.

NUG Facilities connected to and operating in synchronization with the SaskPower BES shall comply with all future revisions and addenda to the above standards at the expense of the NUG Owner.

NUG Owners who are engaging in self-generation must demonstrate that they have made arrangements for reserve requirements (spinning and non-spinning reserve) specified by NERC, or the regulatory agency which may have authority at the time.

WAIVER:

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

1.6. 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 synchronism with SaskPower’s BES.

- NUG Owner submits preliminary proposal that includes the information requested in Appendix A.

- SaskPower will undertake a steady state analysis of the system and provide a preliminary assessment of the interconnection requirements along with budget level (\pm 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 Owner determines that there is a basis for proceeding with the project, a detailed proposal shall be submitted which includes the information requested in Appendix B. SaskPower will conduct the detailed BES 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 transmission lines, there may be up to three years' lead time required. SaskPower will assess a fee for conducting the integration studies.

1.7. 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 TRANSMISSION SYSTEM CHARACTERISTICS

The following information describes the characteristics of the SaskPower Transmission System and identifies a number of aspects which must be considered:

2.1. General System Configuration

The SaskPower Transmission System is an interconnected grid system with system voltages of 230 kV and 138 kV. The 72 kV system is operated primarily as radial feeders. The SaskPower Transmission System is interconnected with Manitoba and the United States through synchronous ties. The SaskPower Transmission System is also interconnected to Alberta via a back-to-back DC tie.

Generator step-up transformers are Δ Y connected (grounded Y on the SaskPower Transmission System side). The Transmission System transformers are solidly grounded autotransformers with Δ tertiary.

The Transmission System is operated under the control of a centrally located Grid Control Centre (GCC) utilizing SaskPower owned, operated and maintained communication systems.

2.2. System Voltage Unbalance

Voltage unbalance on the Transmission System is minimal during normal operation. The voltage unbalance under normal operating conditions will be less than 3 percent. The voltage unbalance is as defined by NEMA MG1-14.33. During faults on SaskPower's Transmission System and within single-pole reclosing cycles, the unbalance will be significant.

2.3. Frequency and Frequency Variation

The nominal frequency of the SaskPower Transmission System is 60 Hz. For steady state operation frequency deviations are within ± 0.02 Hz. Frequency excursions outside of the above range will occur during disturbances. The NUG Facilities shall be designed to accommodate the frequency excursions specified in subsection 4.12.1.

2.4. Steady State Voltage Levels

During normal steady state conditions, the 72 kV and 138 kV systems can vary from 90 percent to 105 percent of nominal voltage. However, under extreme conditions, the 72 kV and 138 kV systems can vary between 85 percent and 105 percent of nominal voltage with some 138 kV facilities designed to operate continuously up to 110 percent of nominal voltage.

The 230 kV system typically operates between 95 percent and 110 percent of nominal voltage; however, the voltage can vary from 85 percent to 110 percent of nominal voltage under extreme conditions.

2.5. System Fault Levels and System Impedances

The fault levels on the SaskPower Transmission System are influenced by numerous factors such as location, generation pattern, and prior outages. For these reasons, fault levels vary over a broad range. Future fault levels will also be influenced by Transmission System expansion and new generation. The expected fault level contribution and equivalent system impedances associated with SaskPower's existing system are available from SaskPower for all switching stations. The NUG Owner is responsible to ensure apparatus can accommodate future increases in the system fault level.

2.6. Fault Clearing

With few exceptions, faults which occur on the 138 kV and 230 kV portions of the SaskPower BES are cleared within 100 msec.

For those situations where time coordination of protection is the determining factor, such as the 72 kV system, the time required to clear faults varies. On the 72 kV system, line-to-ground faults are normally cleared in about one second (with some sacrifice of coordination), whereas, for high impedance ground faults and multi-phase faults, the clearing time may be up to three seconds, or even longer, in a few specific situations. The connection of generation on the 72 kV system, which is currently operated as a radial system, may require upgrading of protection to reduce the fault clearing time. The NUG Owner is responsible for the costs incurred to upgrade protection.

The fault clearing times indicated 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.

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 occurs. The fault clearing time consists of several components such as fault measurement, communications, auxiliary relay operation, breaker tripping, and arc extinction.

2.7. Automatic Reclosing

The SaskPower Transmission System utilizes high-speed automatic reclose for most transmission lines. Automatic reclose normally is applied for single line to ground faults only and is normally blocked for multi-phase faults; however, some older installations may not block for all multi-phase faults. Most of the 230 kV transmission lines utilize single-pole tripping and high-speed reclose. The dead time for three-pole automatic reclose is about 30 cycles (0.5 sec) and for single-pole automatic reclose, it is about 45 cycles (0.750 sec). Only one attempt is made to automatically reclose following a fault. If the initial reclose attempt is unsuccessful, a non-lockout trip occurs which allows further reclose attempts initiated from GCC. At locations where automatic reclose is applied at the 72 kV level, the line dead time is greater than one second.

2.8. System Grounding

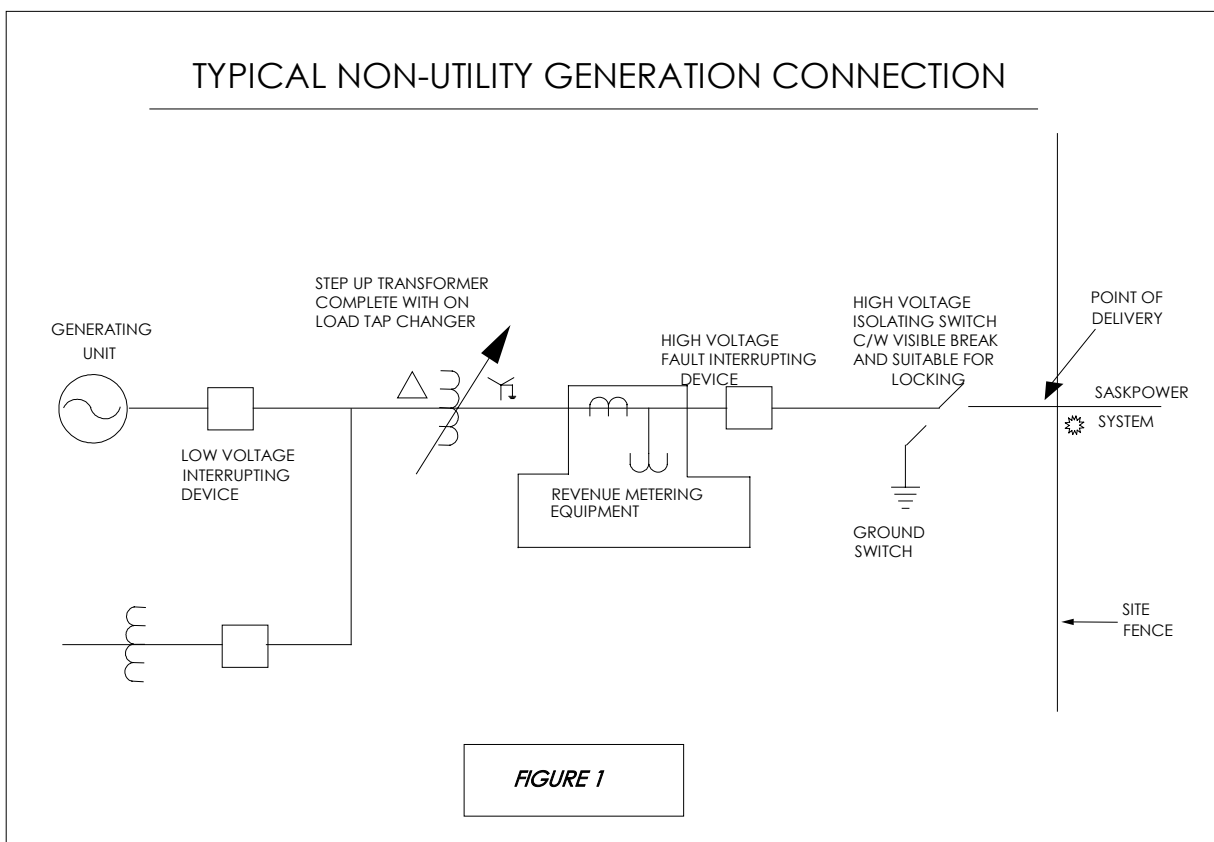
The SaskPower Transmission System has been designed to operate as an effectively grounded system. To accomplish this, all SaskPower-owned generator step-up transformers are Δ Y connected (grounded Y on the SaskPower Transmission System side), and the Transmission System transformers are also solidly grounded autotransformers with Δ tertiaries.

3. INTERCONNECTION FACILITY REQUIREMENTS

The requirements for the Interconnection Facilities are determined based on the characteristics of the SaskPower Transmission System and the characteristics of the proposed NUG Facilities.

3.1. Typical NUG Interconnection

Figure 1 (below) shows a typical generator connection configuration for illustration purposes. Actual configuration may vary.



NOTES:

- Point of Delivery - The dead-end bells on the substation. Refer to the SaskPower "Electric Service Guide" for additional details.
- Maintenance Interface - The dead-end bells on the substation. Refer to the SaskPower "Electric Service Guide" for additional details.
- Operating Interface - High voltage isolating switch.

3.2. Compliance with Standards and All Requirements of Section 3

The NUG Facilities shall comply with CSA standards and the Canadian Electrical Code, where applicable; the requirements outlined in the SaskPower Electric Service Guide; NERC standards and policies; and the standards set by the host Regional Reliability Organization (RRO), with which SaskPower has an agreement.

NUG Owners are responsible to ensure there is full compliance with the requirements of the most current version of the above-named standards and guides. NUG Facilities shall comply with all future revisions and addenda to the above standards at the expense of the NUG Owner.

3.3. Safety

NUG Interconnection Facilities shall be constructed and maintained to provide a safe environment for both employees and the public.

3.4. Equipment Ratings

The NUG Owner shall be responsible for ensuring all aspects of the equipment ratings, such as continuous operation capability, fault withstand capability, and fault interrupting capability in the case of interrupting devices, meet or exceed requirements.

Fault capability requirements shall be determined from short circuit studies. Continuous operation capability requirements shall be based on parameters of the NUG Facilities, such as maximum output capability; however, minimum rating limits shall not be violated.

The NUG Owner is also responsible to ensure correct insulation coordination exists. Insulation requirements shall take into consideration the insulation levels of equipment on the SaskPower Transmission System and other requirements as described in the SaskPower Electric Service Guide.

The NUG Owner is responsible to ensure the capability of the equipment continues to meet the requirements as described in section 3.15.

3.5. Interconnection Voltage

SaskPower shall specify the interconnection voltage based on system requirements determined from the results of system integration studies.

3.6. Substation

3.6.1. General Arrangement Requirements

Refer to the SaskPower Electric Service Guide for the specifications covering phase spacing, lightning protection (shield) wires, dead-end tensions, dead-end heights, dead-end insulation levels, and customer's equipment insulation levels.

3.6.2. Electrical Clearance Requirements

Refer to the SaskPower Electric Service Guide for the specifications covering required clearances.

3.7. Ground Grids

For situations where a SaskPower substation and the NUG substation are within close proximity of each other, consideration shall be given to connecting the substation ground grids together (minimum of two locations). The requirement for interconnection of the ground grids is significantly influenced by the separation distance; however, other aspects, such as soil resistivity and activities between the two sites, can have an impact on the decision to tie the grids together.

For situations where only a transmission line is being terminated at the NUG Facilities, refer to the SaskPower Electric Service Guide for details and requirements.

3.8. Transformer

3.8.1. Winding Configuration

The SaskPower electrical system is designed as an effectively grounded system. All NUG Facilities shall utilize a step up transformer configuration that provides a ground current source which qualifies as effectively grounded. Grounding transformers may be utilized to achieve an effectively grounded system.

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 Transmission 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 owner shall use the generator's direct axis transient reactance. Refer to Terms and Definitions for a further description of effectively grounded systems.

3.8.2. Tap Changer Requirements

The NUG shall match the operating voltage range for the interconnection point that is specified by SaskPower. Typical operating ranges are set out in Section 2.4. The requirement to match the voltage range on the Transmission System may dictate that the step-up transformer be equipped with on-load tap changers.

If the auxiliary equipment within the NUG Facility cannot operate over the range specified in Section 2.4, this may also dictate a requirement for an on-load tap changer.

3.9. High Voltage Fault Interrupting Devices

The Interconnection Facilities shall include a high voltage device rated as per section 3.4 to interrupt potential fault current contributions from the SaskPower Transmission System in the event of a fault within the Interconnection Facilities, or interrupt the fault contribution from the NUG in the event of a fault on the SaskPower Transmission System. The operational speed of the device will be determined by the requirement for fault clearing times as described in Section 2.6.

As per the SaskPower Electric Service Guide, maintenance, safety, and system considerations require a visible break disconnect switch (either motorized or manual) to disconnect the NUG Interconnection Facilities from the transmission line. The disconnect switch shall be connected on the line side of the metering transformers. SaskPower recommends that a three-phase ground switch also be applied on the NUG side of the disconnect switch.

3.10. Protection of Equipment and Detection of Faults

The NUG Facilities must detect all types of faults that occur either on the SaskPower system or within the NUG Facilities. The successful disconnection of the NUG from the SaskPower system, coordinated within the required clearing time, is necessary to ensure public safety and to protect equipment on the SaskPower system and within the NUG Facility.

3.10.1. Faults Within Interconnection Facilities

The NUG Facilities shall be equipped with protection and fault clearing devices to isolate the NUG Facilities from the SaskPower Transmission System during the occurrence of all types of faults within the generator and interconnection facilities, including contingency situations such as failure of the high voltage breakers. Specific requirements regarding allowable clearing time will be defined by SaskPower upon completion of system integration studies; however, high-speed clearing (100 msec or

less) of faults is typically required for any faults on facilities connected to the Transmission System.

3.10.2. Faults on SaskPower's Facilities

The NUG Facilities shall be equipped with protection and fault clearing devices capable of detecting (accurate phase discrimination) and disconnecting the NUG from SaskPower's Transmission System for all types of faults on the SaskPower Transmission System.

The NUG Facilities shall be equipped with protection systems that coordinate with adjacent protection systems to isolate the faulted element only. At SaskPower's determination, the NUG Facilities shall be equipped with dedicated communications to facilitate clearing of line faults. Dedicated communications may also be a requirement in order to provide breaker failure protection.

Clearing of faults shall be as outlined in section 2.6 or as determined by the integration study. The NUG Facilities which are connected to the Transmission System (138 kV and above) shall be equipped with dual protection schemes for the detection of faults on SaskPower's Transmission System. For those NUG Facilities connected at 72 kV, the NUG Facilities shall be equipped with main and backup protection.

The NUG Owner shall provide study results which support the proposed choice of type of transmission line protection.

3.10.3. Protection From Abnormal Conditions

The NUG Owner is responsible to ensure that the NUG Facilities are protected from the effects of abnormal conditions on SaskPower's Transmission System such as lightning, resonance conditions, faults, harmonics from others, geomagnetic induced current (GIC), self-excitation and switching surges (natural aspects of electrical systems). The NUG must be self-protecting to prevent damage as a result of normal or abnormal operation of the SaskPower Transmission System. The NUG Owner is accountable for the execution of studies to identify potential abnormal conditions and is also accountable for the cost of mitigation.

3.10.4. Special Protection Systems

Depending on the location of the NUG Facilities, special protection schemes may be required as part of integrating the NUG Facilities into the SaskPower Transmission System. Special protection systems may include, but are not limited to, generator run back or generator dumping schemes. The NUG Owner will be required to participate and shall be responsible for costs incurred.

3.10.5. Protection Equipment

All components of the protection systems installed within the NUG Facilities shall meet the standards for relays and relay systems as defined by ANSI C37.90, ANSI C37.90.1 and ANSI C37.100 or most recent update.

3.10.6. Protection Coordination

There is a requirement that the NUG Facilities protection systems coordinate with the SaskPower protection system. To ensure these requirements are met, the NUG Owner shall submit all proposed relay settings to SaskPower for review of protection coordination.

The NUG Owner is responsible for keeping abreast of future changes and for undertaking these changes to the NUG Facilities. In addition, when advised by SaskPower, the NUG Owner will make changes to the NUG Facilities as requested by SaskPower. All future relay setting changes shall also be submitted to SaskPower for

review of protection coordination. The NUG Owner will be responsible for the costs of any required changes.

The NUG Owner is responsible to ensure the NUG Facilities protection systems provide appropriate protection for the NUG Facilities and interconnecting SaskPower facilities.

3.10.7. Testing of Protective Relay Systems

The NUG Owner shall make provisions to allow for proper testing and commissioning of protection systems during both the initial construction period and subsequent maintenance and retest intervals. The NUG Owner shall provide at least thirty (30) days notice of planned tests to SaskPower in order that SaskPower may witness such tests. The required tests include those tests recommended by the supplier of the equipment and any additional tests identified by SaskPower, such as injection of protection systems with test data derived from electrical system simulation studies. Some of the required tests will require the use of sophisticated test equipment. Protection systems that require communications to achieve performance requirements must be tested from end to end to verify the integrity of the facilities and the operational reliability of said systems. The NUG Owner must provide a certified copy of test results to SaskPower for review. SaskPower reserves the right to request additional tests or repeat of tests where results appear questionable. SaskPower reserves the right to witness any or all of the tests.

The NUG Owner is responsible to ensure the protection systems are maintained and retested following the practices and procedures recommended by the manufacturer and any additional requirements requested by SaskPower. SaskPower reserves the right to request copies of all maintenance records and retest results.

3.11. Sequence of Event Recording

Any NUG Facility which has total installed capacity in excess of 10 MW shall have accurately time-tagged sequence-of-event recording (SER) equipment installed to facilitate analysis of faults and normal operational activity. Depending on location and system conditions, SaskPower may specify that SERs be installed on units of less than 10 MW.

3.12. Communications

As part of the interconnection facilities, SaskPower may specify that dedicated communications systems be installed for protection and monitoring (SCADA-RTU). Since the communications facilities become part of an integrated system, SaskPower may choose to acquire the terminal equipment that would be installed within the NUG Facilities. The NUG Owner shall provide space in an environmentally controlled building for the terminal equipment along with a secure power source for the equipment and shall provide SaskPower with full access at all times.

In addition to the dedicated communication facilities that may be required for protection and monitoring, units greater than 10 MW in size shall include an "operational voice" communication system required for dedicated communications with SaskPower's GCC.

Special electrical protection equipment (e.g., equipment to mitigate the consequences of ground potential rise) may be necessary on SaskTel communication equipment. The NUG Owner is advised to contact SaskTel for requirements and costs.

3.13. Monitoring of Interconnection Facilities

For NUG generators with a capacity greater than 10 MW, and when required for units under 10 MW (i.e., due to location on the Transmission System), a remote terminal unit (RTU) shall be installed at the NUG site to provide monitoring and status information to SaskPower's GCC. Communication between the GCC and the RTU will be via dedicated communication facilities. Since the RTU must be compatible with the SaskPower SCADA master system, the RTU will be acquired by SaskPower. The cost of the RTU and communication facilities or modification to existing communication facilities shall be born by the NUG Owner. The NUG Owner shall

provide adequate space in an environmentally controlled building for the terminal equipment along with a secure power source for the equipment and provide SaskPower with full access at all times. The RTU will provide the following data:

- Status of high voltage interrupting device (and motorized disconnects if applied)
- Status of low voltage interrupting device (if applied)
- Net MW and Mvar delivered at point of delivery
- Frequency and voltage on high voltage bus of NUG interconnecting substation

3.14. Metering

The NUG Owner is responsible for the supply and cost of the revenue metering equipment including PTs and CTs. Metering equipment shall be revenue approved pursuant to the Electricity and Gas Inspections Act (Canada). At the NUG Owner's option (and cost), SaskPower will supply and install the metering equipment including required CTs and PTs. If the NUG Owner chooses to have SaskPower supply and install the metering equipment, the NUG Owner shall provide space for metering equipment within an environmentally controlled building and provide a suitable structure(s) for mounting PT's and CT's as outlined in SaskPower's Electric Service Guide. The NUG Owner shall provide and install the conduit for CT and PT cables between the metering unit and the indoor metering location.

The metering equipment shall be dual register metering capable of recording real and reactive power delivery to and from the NUG Facility separately.

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

For further details and up-to-date requirements refer to the SaskPower "Electric Service Guide".

3.15. 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 Interconnection Facilities in response to meet new or revised standards or due to system changes, and, therefore, make provision to accommodate changes efficiently. Some examples of potential Interconnection Facilities changes include replacement of equipment due to a requirement for increased interrupting capability, harmonic filter re-tuning or mitigation of motor starting voltage fluctuations due to a change in system impedance; protective relay upgrades to enhance functionality or reduce fault clearing time for system needs; and the addition of power factor correction equipment. The NUG Owner shall be responsible for the cost of any required changes.

4. NON-UTILITY GENERATION FACILITIES REQUIREMENTS

The following requirements pertain to the installation and operation of conventional synchronous generators. Other types of generators will be considered on an individual case basis. When standards and guidelines are referenced, the NUG Owner is responsible to ensure that the most up-to-date versions are implemented within the NUG Facilities. NUG Facilities shall also comply with all future revisions and addenda to the above standards at the expense of the NUG Owner.

4.1. General

Synchronous generators shall be equipped with a high-speed voltage regulator. The voltage regulator and exciter system shall be capable of controlling the generator terminal voltage, without hunting, within 0.5 percent of any voltage level (set point) between 95 and 105 percent of the rated generator voltage, provided the generator is operating within its (MVA) capability limits.

Excitation systems for synchronous generators larger than 10 MVA, rated capacity, shall be specified as high initial response (HIR) as defined by IEEE Standard 421.

Synchronous generators shall be capable of delivering rated output power at a power factor of between +0.9 (lagging) and -0.95 (leading).

Synchronous generators shall be capable of operating during unbalanced conditions associated with single-phase Transmission System faults with single-pole, high-speed (45 cycle dead time) auto reclose.

Synchronous generators shall be in compliance with most recent applicable ANSI standards C50.10, C50.12, C50.13 and C50.14 for synchronous generators.

The voltage set point that the NUG Facility is required to maintain shall be specified by SaskPower's GCC.

4.2. Excitation System Requirements

4.2.1. Rated Current

The excitation system shall be capable of delivering continuously, at rated ambient temperature and within rated temperature rise, any value of field current from 0 to 110 percent of the field current required by the generator at maximum overexcited capability, rated power factor, and over the full generator operating voltage range.

4.2.2. Ceiling Current

The excitation system shall be capable of providing a ceiling current to the field of not less than 1.6 times rated field current for 30 seconds. For a solid state excitation system, the ceiling current shall be attainable with one paralleled bridge removed.

4.2.3. Field Current at Reduced Voltage

The excitation system shall be capable of continuous operation at full rated continuous current output at excitation system supply voltages ranging from 80 percent to 110 percent of generator-rated voltage. The entire excitation system shall also be capable of operation at supply voltages of less than 80 percent of generator rated voltage for loads, durations, and frequencies consistent with the generator manufacturer's runup and shutdown regimes, and with fault duty requirements.

4.2.4. Ceiling Voltage

Ceiling voltage requirements are typically determined by system integration studies that include an assessment of transient stability. In cases where integration studies have not yet been conducted or machine characteristics are not well defined, the following may be used to establish a minimum requirement. Once integration studies, based on actual machine design parameters, are completed, the ceiling voltage requirements may be increased, if required.

With exciter supply voltage, generator terminal voltage and field current at rated value, the exciter ceiling voltage shall not initially be less than 2 times the excitation field voltage required for rated load field current, when the field temperature is defined by IEEE-421.

At rated supply voltage and field current equal to 1.6 times generator rated field current, exciter ceiling voltage shall be not less than 1.7 times generator rated load field voltage as defined in IEEE-421.

In excitation systems where the ac supply voltage can be less than the rated value, the ceiling voltage may be reduced approximately in proportion to the reduction in supply voltage. Following restoration of the supply voltage, the excitation system shall be capable of immediately going to ceiling voltage.

With positive field current flowing, the excitation system shall be capable of supplying an adjustable negative ceiling voltage up to at least 70% of corresponding positive ceiling voltage positive field voltage defined above.

The excitation system shall not be required to supply negative field current unless the system integration studies identify a requirement.

4.2.5. Large Signal Response

HIR excitation System Voltage Response Time shall be equal to or less than 25 milliseconds for a 5% deviation in terminal voltage, with the open loop DC gain of 200.

For a non-high initial response excitation system, the response ratio as defined in IEEE-421 shall be at least 1.0 per unit/second.

4.2.6. Small Signal Response

The voltage regulating open loop DC gain (with the generator on open circuit and assuming operation on the air gap line) shall be adjustable either continuously or in steps between 25 and 500. The gain characteristic shall be linear, with the typical operating gain setting of approximately 200 located in the middle of the range of adjustment. Maximum overshoot of generator output voltage to a step change when the generator is separated from the system under any conditions shall not exceed 30 percent, and shall be damped so that the number of swings does not exceed 2, nor extend beyond 2 seconds.

4.2.7. Requirements Under System Fault Conditions

The excitation system shall not trip, and shall continue to operate during faults on the high voltage (HV) components of SaskPower's Electric System, and shall recover and return to normal operation immediately after 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 due to various HV faults.

The excitation system shall be capable of withstanding switching surge voltages which may reach 2.5 times nominal supply voltage values and may persist for several cycles (60 Hz time basis).

The excitation system shall be capable of withstanding 60 Hz dynamic overvoltages caused by load rejections as high as 1.5 times normal generator terminal voltage for several seconds.

Under system fault conditions, the excitation shall perform as described below, assuming initial loading at rating:

Case 1: Three-Phase Fault

A three-phase fault occurs on the high voltage bus. A high voltage breaker fails to clear the fault (stuck breaker). A backup breaker clears and isolates the fault. The generator remains on line, and returns to normal operation. Table A1 below provides the approximate timing for the sequence of events.

Table A1: Three-Phase Fault Timing and Sequence of Events

Time	Description
At 0 cycles	phase high voltage fault occurs.
From 0 cycles to 21 cycles	The exciter goes to maximum available ceiling voltage.
At 21 cycles	The 3-phase fault is cleared.
From 21 cycles to 30 seconds	The exciter continues to operate at ceiling voltage until the field current equals 1.6 times rated field current; then at the voltage required to maintain this ceiling current (the exciter is assumed to maintain full ceiling current for rating the thermal side of the exciter).
Beyond 30 seconds	Exciter returns to, and continues, normal operation.

Case 2: Single Phase to Ground Fault

A single phase to ground fault occurs on a high voltage transmission within the vicinity of the generation facilities. The fault on that phase is cleared by a single-pole breaker operation. The breaker recloses on the fault, then all three poles of the line breaker open. The generator remains on line, and returns to normal operation. Table A2 below provides the approximate timing for the sequence of events.

Table A2: Single Phase to Ground Timing and Sequence of Events

Time	Description
At 0 cycles	phase to ground fault occurs on a high voltage line.
From 0 cycles to 6 cycles	The exciter goes to maximum available ceiling voltage.
At 6 cycles	The 1 phase to ground fault is cleared and the 2 unfaulted phases remain connected.
From 6 cycles to 51 cycles	The exciter remains at ceiling voltage, attempting to restore generator voltage.
At 51 cycles	The 1 phase to ground fault is reconnected.
From 51 cycles to 57 cycles	The exciter remains at maximum available ceiling voltage.
At 57 cycles	The line is tripped.
From 57 cycles to 30 seconds	The exciter remains at ceiling voltage until field current equals 1.6 times rated field current; then at the voltage required to maintain this ceiling current (the exciter is assumed to maintain full ceiling current for rating the thermal side of the exciter).
Beyond 30 seconds	Exciter returns to, and continues, normal operation.

4.2.8. Automatic Voltage Regulator (AVR)

An automatic voltage regulator shall be provided, having a negligible deadband and small signal response characteristics that enhance the transient stability of the generator (e.g., transient gain reduction or rate feedback).

The voltage regulator shall have the capability to control the terminal voltage of the generator continuously between 80 percent and the upper limit of the rated voltage of the generator from no load to full load, with a resolution not exceeding 0.5 percent, and of covering this range linearly in approximately 1 minute.

4.2.9. Manual Excitation Control

On loss of generator potential transformer signal or on voltage regulator failure, the exciter shall transfer to manual control. This transfer shall be alarmed. Capability to manually transfer from automatic control to manual control shall be provided.

An automatic follow-up circuit shall be provided for the manual control so that on transfer from AVR control to manual control a “bumpless” transfer will result.

To facilitate generator testing, it shall be possible to operate in a manual field voltage control mode.

4.2.10. Reactive Current Compensation

A reactive current compensation circuit shall be provided to permit the AVR to control voltage at a point remote to where the generator voltage is measured. The point of control shall be continuously adjustable over a range of 0 to +15 percent reactance (on generator base) beyond the generator terminals.

Where units are paralleled on the low voltage side of their unit transformer, either cross current compensation should be provided or provision made to reverse the above compensation circuit, to allow units to share reactive power load.

4.2.11. Over Excitation Limiter (OEL)

An OEL shall be provided to limit the generator field current to a safe value and protect the generator field. The generator shall ramp down the excitation gradually once the time limit of the field overcurrent has been reached.

The OEL shall coordinate with the rotor capability characteristic, as defined by ANSI, as close as possible. The OEL shall be provided with a rotor heating memory feature to prevent rotor overheating under conditions of repetitive field forcing.

The OEL shall not be designed to trip the generator, unless necessary to protect the generator from damage.

The OEL shall not prevent the excitation system from going to ceiling during fault conditions, when field currents can exceed the limit settings.

The OEL shall operate in AVR and manual modes of regulator control.

4.2.12. Under Excitation Limiter (UEL)

A slow acting limiter shall be provided to prevent an operator or other control from inadvertently lowering the set point beyond a stability or thermal limit.

4.2.13. Power System Stabilizer (PSS)

Power System Stabilizers shall be applied to all generators greater than 75 MW in size. Depending upon location, and system conditions, power system stabilizers may be required on smaller units or groups of smaller units, as determined by the results of the integration studies.

4.3. Synchronizing Facilities

The NUG Facility shall be equipped with automatic synchronizing equipment. For synchronizing generators, the synchronizing system consists of a synchronizer equipped with speed matching and voltage matching control capability and a synchronism check relay to block closing if the angle difference exceeds the limit. This equipment is required to minimize the synchronizing impact on the system. The settings on these relays and the logic schematic drawings must be submitted to SaskPower for review to ensure that generator synchronizing will not adversely affect the operation of SaskPower's Transmission System. The generator shall not be synchronized to the SaskPower Transmission System whenever generator voltage regulation is not available without permission from SaskPower. The NUG Owner is responsible for synchronizing its generator to SaskPower's Transmission System following instructions from the SaskPower GCC.

4.4. Automatic Generator Control (AGC)

If the NUG is providing AGC service to SaskPower, the NUG Owner shall be responsible to provide an interface on its governor control that will accept an increase/decrease load signal from SaskPower's RTU. The rate at which the unit is to respond will be determined as part of the negotiation for the provision of this service.

4.5. Station Service

The NUG Owner is responsible to determine station service requirements for all operating conditions, such as post-contingency situations.

4.6. Black-Start Capability

If the NUG is providing black-start capability, the requirements for governor and voltage control, and synchronizing capability will be determined as part of the negotiation for the provision of this service.

4.7. Load Rejection

Faults on the SaskPower Transmission System may result in the disconnection of the generator from all load. The NUG generators shall be capable of withstanding the subsequent full load rejection.

4.8. Synchronous Compensator Operation

Depending upon location, type, size and intended operation of the unit, SaskPower may request the NUG Owner to install compensator capability. Details around synchronous compensator operation will be determined as part of the negotiation for the provision of this service.

4.9. Power Quality

Operation of the NUG Facility shall not result in deterioration of the power quality on SaskPower's Transmission System.

4.9.1. Voltage Fluctuation

The NUG Owner shall ensure the operation of the generator will not cause excessive voltage fluctuations or flicker on SaskPower's Transmission System. The Voltage Flicker limits, as measured at the point of delivery, are defined in the SaskPower Electric Service Guide.

4.9.2. Voltage Distortion

The voltage distortion limits shall meet with the general requirements for synchronous machines as described in ANSI G50.10 1990 or the most recent update.

4.10. System Unbalance/Negative Sequence

The generator shall be able to withstand the effect of negative sequence current resulting from system disturbances. The most common cause of system unbalance on the Transmission System will be unbalanced faults and single-pole tripping and reclose; however, other factors which may result in negative sequence current, such as steady state system voltage unbalance, should also be evaluated for impact. SaskPower reclose practices are described in Section 2.7.

4.11. Generator Protection

The NUG Owner shall ensure that the generator is protected from all abnormal conditions.

NUG protection settings shall coordinate with the SaskPower protection. The NUG Owner shall submit proposed relay settings to SaskPower for review. Any subsequent relay setting changes shall also be submitted to SaskPower.

4.12. Governor Operation and Frequency Control

All generators shall be required to have speed governors on their prime movers that sense frequency and contribute to frequency control on the SaskPower Transmission System. Governors shall have a droop setting that is adjustable from 0 to 10 percent.

4.12.1. Short-Term Off-Frequency Operation

Generators 10 MW or larger shall have a short-time capability for off-frequency operation which shall not be less than the following:

60 to	59.5 hertz	Continuous
59.5 to	59.3 hertz	10 minutes
59.3 to	58.7 hertz	10 seconds

Frequency relays that would constrain the operation of the facility to less than the above limits shall not be permitted unless otherwise agreed to by SaskPower.

4.12.2. Power Island Condition

NUG Facilities shall not operate as a power island connected to SaskPower customers, unless explicitly granted approval by SaskPower to do so. All NUG Facilities shall have local under- and over-frequency protection that will disconnect the NUG Facility from SaskPower's Transmission System. The under- and-over-frequency protection shall coordinate with other protection on the SaskPower system. In addition to local protection, dedicated communications shall be installed at the NUG Owner's expense to help ensure disconnection of the NUG for islanding situations.

4.13. Performance Testing and Machine Parameter Validation

The NUG Owner shall undertake sufficient testing to confirm the dynamic performance of the generator control system and to verify the machine parameters that will be used for modeling and stability analysis. Performance tests are not intended to verify plant design, protection or any other aspects of the facilities even though performance tests may reveal deficiencies. The NUG Owner shall undertake tests to confirm the capability ratings of each generator.

The NUG Owner shall make provision within the design to facilitate proper testing of equipment during the initial construction/commissioning period, periodic re-tests following unit maintenance and following unit modifications as required.

The NUG Owner shall provide SaskPower with the proposed test plan for review prior to testing and shall provide SaskPower with reasonable opportunity to witness any or all of the tests.

4.13.1. Generator Size

The requirement to test and verify machine parameters will normally be restricted to units of 10 MW and larger; however, in certain situations, i.e., location on the system, some or all of the tests may be required for units less than 10 MW. The need for testing of smaller units will be identified by SaskPower on an individual unit basis.

4.13.2. Test Standards**4.13.2.1. Dynamic Performance Testing and Parameter Validation**

New generators shall be tested in accordance with NERC requirements for Generation owners. Testing is also required to verify compliance with these requirements, or other contractual requirements, and to demonstrate acceptable performance. There may also be additional requirements specified by the host RRO, with which SaskPower has an agreement.

4.13.2.2. Machine Output Capability

On an annual basis, each generator within the facility shall be tested in accordance with the Mid-Continent Area Power Pool (MAPP) URGE (uniform rating of generating equipment) test procedures for the RRO, with which SaskPower has an agreement (currently MAPP). The specific MAPP test requirements vary depending on the type of prime mover. These guidelines can be found at the MAPP web site <http://www.mapp.org>.

4.13.3. Processes and Test Results

The NUG Owner is responsible for determining the appropriate tests and the proper test processes for the particular type and rating of generator being tested. The NUG Owner is also responsible for providing SaskPower with the associated engineering reports.

4.13.3.1. Dynamic Performance Tests and Parameter Measurements

Dynamic performance tests and machine parameter measurements include, but are not limited to:

- Governor response tests;
- Automatic voltage regulator (AVR) and exciter response test;
- Power System Stabilizer (PSS) response tests;
- Machine parameter validation tests;
- Steady state tests;
- Capability tests; and
- Limiter tests.

4.13.3.2. Machine Capability Tests

Machine capability tests shall be conducted annually for each individual unit within the facility and the results provided to SaskPower.

Following receipt of the test data, SaskPower will review the data and either accept the test results or request further testing in the form of additional tests or the repeat of tests.

4.14. 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. Some examples of potential requirements for generator facility changes include the addition of a PSS or other control feature or changes to a PSS, AVR, or governor settings or limiters, if required by future system conditions, or changes to accommodate new or revised standards. The NUG Owner shall be responsible for the cost of any required changes.

TERMS AND DEFINITIONS

AGC	Automatic Generator Control
ANSI	American National Standards Institute or any successor organization or assigns.
AVR	Automatic Voltage Regulator
Bulk Electric System or BES	The bulk electric system is a term commonly applied to that portion of an electric utility system which encompasses the electrical generation resources, transmission lines, interconnections with neighbouring systems, and associated equipment, generally operated at voltages of 100 kV or higher. In Saskatchewan, the bulk electric system also includes those portions of the 72 kV system which are utilized to connect generation and bulk customers to the rest of the bulk electric system.
CSA	Canadian Standards Association or any successor organization or assigns.
Effectively Grounded System	<p>AIEE Standard No. 32-1.05, May 1947, defines effective grounding as follows:</p> <p>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.)</p>
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
Interconnected Operations Services or IOS	A service (exclusive of basic energy and transmission services) that is required to support the reliable operation of interconnected Bulk Electric Systems as defined by NERC standard (Draft) policy 10.
Interconnection Facilities	<p>This includes but is not limited to:</p> <ul style="list-style-type: none">■ 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.
	<ul style="list-style-type: none"> ■ Generator step-up transformer complete with on-load tap changer. ■ Communications, protection and control facilities. ■ Metering equipment. ■ Special protection systems.
MAPP	Mid-Continent Area Power Pool or any successor organization or assigns.
NEMA	National Electrical Manufacturers Association or any successor organization or assigns.
NERC	North American Electric Reliability Council or any successor organization or assigns.
Non-Utility Generation or NUG	<p>Generation connected to the SaskPower Transmission System which is not exclusively owned by SaskPower. This includes:</p> <ul style="list-style-type: none"> ■ <u>Co-Generation</u> - the simultaneous generation in one plant of electricity and useful thermal or mechanical energy with the electrical energy being sold to the utility. ■ <u>Independent Power Production</u> - investor-owned facilities dedicated exclusively to the generation of electrical energy. ■ <u>Self-Generation</u> – 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.
NUG Owner	The owner of the non-utility generation facilities.
OEL	Over-excitation limiter
PSS	Power System Stabilizer
Reclose Dead Time	Time interval between the removal of the supply and restoration of supply.
RRO	Regional Reliability Organization, currently the Mid-Continent Area Power Pool, or any successor organization or assigns.
RTU	Remote terminal unit
SCADA	Supervisory control and data acquisition
Transmission System	Interconnected group of electric transmission lines and associated equipment for the movement or transfer of electric energy in bulk between points of supply and points of delivery.
UEL	Under-excitation limiter

APPENDIX A: PRELIMINARY INTERCONNECTION DATA REQUIREMENT

PROJECT OWNER	
Company:	
Representative:	
Mailing Address:	
Telephone Number:	
SITE LOCATION AND IN-SERVICE DATE	
Proposed Location of Project:	
Proposed In-Service Date:	
GENERATOR DATA	
Type (synchronous, etc.):	
Rated Output (MW):	
Power Factor at rated output (%):	
Energy Source: (Co-gen, combined cycle, gas turbine, etc.)	
Expected mode of operation: (base-load, peaking)	
TRANSFORMER DATA (if available)	
Rating (MV.A ONAN/ONAF):	
Winding connections:	
Positive sequence impedance: (% on ONAN base)	
Zero sequence impedance: (% on ONAN base)	
DRAWINGS	
General site location map showing location of NUG Facility	
Preliminary protection and metering single line	

APPENDIX B: FINAL GENERATOR CONNECTION DATA REQUIREMENTS

The NUG Owner shall submit detailed information as required to model the transient, dynamic and steady state behavior of the generator in system integration studies. The NUG Owner is responsible for ensuring that the data submitted provides an adequate mathematical representation of the generating facility's electric behavior.

Such information shall include:

1. Generator

- Nameplate data.
- T'_{do} (D-axis unsaturated transient time constant, sec)
- T''_{do} (D-axis unsaturated subtransient time constant, sec)
- T'_{qo} (Q-axis unsaturated transient time constant, sec)
- T''_{qo} (Q-axis unsaturated subtransient time constant, sec)
- H (Inertia constant of generator & turbine, MW-sec/MVA)
- D (Damping factor, pu)
- X_d (D-axis unsaturated synchronous reactance, pu on generator rating)
- X_q (Q-axis unsaturated synchronous reactance, pu on generator rating)
- X'_d (D-axis unsaturated transient reactance, pu on generator rating)
- X'_q (Q-axis unsaturated transient reactance, pu on generator rating)
- X''_d (D-axis unsaturated subtransient reactance, pu on generator rating)
- X''_q (Q-axis unsaturated subtransient reactance, pu on generator rating)
- X_l (stator leakage reactance, pu on generator rating)
- $Se(1.0)$ (saturation factor at 1.0 pu flux)
- $Se(1.2)$ (saturation factor at 1.2 pu flux)
- R_a (stator resistance, pu on generator rating)
- Estimated or calculated saturation curves, V- curves, capability curves or other applicable information.

2. Excitation, Governor and Power System Stabilizer (PSS)

- Identify the type of excitation, governor and PSS systems (from IEEE Standards).
- Provide functional descriptions, block diagrams and all associated gains, droop settings, time constants, compensator characteristics and limiter values in ¹PSS/E format.

3. Step Up Transformer

- Generator step up transformer rating (at -20, 0 and +30 degrees C), winding/grounding configuration, positive and zero sequence impedances and tapchanger configuration.

4. High Voltage Interrupting Device

- 4.1. Type (breaker, circuit switcher)
- 4.2. Voltage rating
- 4.3. Interrupting rating
- 4.4. Operating time (fault interrupting) Opening:
Closing:

¹ PSS/E (written by Power Technologies Inc.) is the industry standard software package used by the reliability region which SaskPower is associated. SaskPower is required to report data to the region in PSS/e format.

5. Drawings

- 5.1. Site plan
- 5.2. Substation layout drawing
- 5.3. Protection single line drawings
- 5.4. Metering

APPENDIX C: OPERATING AGREEMENT

In addition to negotiating and signing the Power Purchase Agreement and the Interconnection Agreement, the NUG Owner will be required to negotiate and sign an operating 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;
- 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 the SaskPower Transmission System,
 - Fault within NUG Facilities,
 - Request from GCC.

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