Technical Requirements

For Connecting Distributed Resources
To The Manitoba Hydro Distribution System
DRG2003

revision 2.1
January 2011

Manitoba Hydro
POWER SMART

Legislative Authority

Section 15(5) of The Manitoba Hydro Act authorizes Manitoba Hydro to set, coordinate and enforce standards for the security, reliability and quality control of the transmission and distribution lines, of any person whose lines are interconnected with the transmission and distribution lines of Manitoba Hydro. Pursuant to section 10 of Regulation 186/90 – Electric Power Terms and Conditions of Supply, Manitoba Hydro is authorized to determine the voltage, frequency, phasing and other characteristics of power, the determination of which is final and binding on the user. Pursuant to this legislative authority, Manitoba Hydro has established the following technical requirements for interconnection of distributed resources.

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Appendices

Revisions

Revision	Date	Changes
Revision 2.1	January 2011	▪ Revised telemetry requirements.
Revision 2	June 2010	▪ Revised specification to reflect adoption of new CSA Standard C22.3 No.9-08 "Interconnection of distributed resources and electricity supply systems".
Revision 1	January 2006	▪ Revised title ▪ Removed reference to policy and procedures as this will be covered in other documents ▪ Established four interconnection types ▪ Added Annex E and F ▪ Revised data sheet
Revision 0	January 2003	

Preface

This document is Manitoba Hydro's technical specification for connecting distributed resources to the Manitoba Hydro distribution system. The previous revision of document, DRG2003 rev. 01, "Technical Requirements for Connecting Distributed Resources To The Manitoba Hydro System" was written prior to release of CSA Standard C22.3 No. 9-08 "Interconnection of distributed resources and electricity supply systems". The numbering in DRG2003 has been changed to reflect the contents of C22.3. Some sections of C22.3 are not applicable within Manitoba Hydro and will be omitted. In addition, certain sections will include information based on CSA C22.2 No. 257-06 "Interconnecting inverter-based micro-distributed resources to distribution systems".

The purpose of DRG2003 is to:

- explain some of the technical requirements in C22.3 No. 9-08 and outline how each section applies to interconnections with the Manitoba Hydro distribution system
- help with interconnection studies

1.0 Scope

This document establishes guidelines and specifies the technical requirements for the interconnection of distributed resources (DR) to the distribution system at 50kV (50,000 volts) and less, up to 10 MW. Interconnected means that the generating facility is operating, or has the ability to operate, in parallel with the Manitoba Hydro distribution system. This includes single phase and 3 phase generating systems, however, single phase generators are limited to 50 kW. (see Table 1.0.1) For voltages above 50kV or aggregate sizes of above 10MW, see Manitoba Hydro document "Technical Requirements for Facility Connection to the Manitoba Hydro Interconnected Transmission System Generally at 60 KV and Above".

Voltage	Generator	Size
50kV and less	Single Phase	Up to 50 kW
	Three Phase	Up to 10 MW

Table 1.0.1 Size and type of generator

Manitoba Hydro reserves the right to set a limit for the maximum size of the DR interconnection that is less than 10MW. Certain circumstances may arise when the technology, the system strength, or the proximity to other DR installations will limit the size of the DR to less than 10MW. Also, if it is determined that the proposed DR interconnection will have an impact on the transmission system, the DR owner will be required to meet the requirements outlined in "Technical Requirements for Facility Connection to the Manitoba Hydro Interconnected Transmission System Generally at 60 KV and Above" as well as follow Manitoba Hydro's Open Access Interconnection Tariff (OAIT).

This specification covers the interconnection of inverter-based and generator-based DR systems and distribution systems where the point of common coupling (PCC) is at low or medium voltage.

The primary purpose of this guideline is to ensure the safety of personnel working in the generating facility, Manitoba Hydro personnel working on the distribution system, and the general public. This guideline is also written to ensure that DR interconnections do not adversely impact the power quality or reliability of the Manitoba Hydro system.

This document is not an operating agreement and as such, does not address metering, rates, tariffs and other contractual issues. It also does not address nor apply to secondary network connections, protection of the DR owner's other equipment, transmission system impact and upgrades, planning, design, and operation of the distribution system, nor the interconnection of distributed resources and distribution systems that are not connected to the Manitoba Hydro transmission grid (i.e. remote diesel locations).

2.0 Reference publications

Manitoba Hydro has other documents related to the interconnection of DR to the distribution system. A listing of these documents along with other reference publications can be found in Appendix A.

3.0 Definitions

Automatic Circuit Recloser (ACR)
An overcurrent protection device used by utilities to detect faults on distribution feeders. It has the ability to open then reclose after a specified time allowing enough time for temporary faults to clear.

Cogeneration
A process that uses excess energy bi-products produced by a facility's process to drive a generator and produce electricity. Eg., a plant that uses a large kiln to dry lumber may recover the wasted heat exiting the stack and use it in a steam system to drive a turbine generator and produce electricity. If more electricity is produced than is required by the facility, the excess is typically exported to the utility.

Disconnecting means
A device or group of devices that allows the conductors of a circuit to be disconnected from their source of supply.

Distributed Generation (DG)
Electric power generation facilities interconnected with the utility through a point of common coupling. They are a subset of DR.

Distributed Resource (DR)
A collective term referring to all sources of real electric power that are not directly connected to the bulk power transmission system. This includes both generators and energy storage devices.

Distributed Resources Interconnection Process (DRIP)
The procedure that Manitoba Hydro uses for evaluating and assisting with the installation of DR systems. This consists of several stages (exploratory, preliminary, study, agreement, and commissioning) and includes the operating agreement.

Distributed resource (DR) system
Typically consists of a fuel source, energy conversion technology, and an electrical interface to the electrical distribution system. The following are some typical combinations:

Fuel Source	Energy Conversion	Interconnection
Sunlight	Solar Panel	DC to AC Inverter
Diesel Fuel	Reciprocating Engine	Synchronous Generator
Hydrogen	Fuel Cell	DC to AC Inverter
Natural Gas	Turbine	Synchronous Generator
Wind	Wind Turbine	Induction Generator
Biomass	Sterling Engine	Induction Generator

Note that the interconnection type is not limited to what is listed in the table. For example, a wind turbine could use a synchronous generator, an induction generator, a doubly fed induction generator, or some type of inverter interconnection.

Distribution System
The portion of the electrical system operating at 50kV (50,000 volts) or less and delivering power to a Point of Common Coupling (PCC) between the utility and a customer.

Independent Power Producer (IPP)
Any non-utility generator interconnected with Manitoba Hydro solely for the purpose of exporting power.

Islanding
A scenario where a portion of the utility's distribution system is energized exclusively by one or more power producers through their DR interconnection.

Momentary Closed Transition
A phrase that refers to a generator that operates in parallel with the power utility for a brief period (≤100ms).

Non-utility generation (NUG)
This term has been replaced with "distributed resource".

Parallel Operation
Any electrical connection between the utility distribution system and the power producer's generating facility.

Point of Common Coupling (PCC)
The location on the Manitoba Hydro system electrically nearest to the customer installation. It can be located on either the primary or secondary side of a supply transformer depending on a) who owns the transformer, and b) whether multiple customers are (or will be) supplied from the secondary of the transformer.

Point of Interconnection (POI)
The location of the electrical connection between a power producer's DR facility and the utility's distribution system. Normally, this is the point where ownership changes from Manitoba Hydro to customer.

Power Producer
Any customer who is interconnected for parallel operation with the Manitoba Hydro distribution system.

Protection Scheme
The protection functions, including associated sensors, relays, and power supplies, intended to protect a distribution system or interconnection equipment.

Sustained Closed Transition
This is the same as parallel operation, or closed transition for periods greater than 100ms.

Target
A supplementary device operated either mechanically or electrically, to visually indicate that a relay or other device has operated or completed its function.

Telemetering
Transmission of measured electrical signals using telecommunications techniques.

Transfer Trip
A remote signal directed from another protective device to command the interconnection system to isolate from the utility during operation.

4.0 General requirements

When planning, designing, and operating an interconnection system, the owner shall abide by all limits specified in Manitoba Hydro specification - PQS2000-01 for THD and flicker. Also, Manitoba Hydro will follow DRIP when evaluating and reviewing requests for interconnections that meet the specifications outlined in Section1.1. The DRIP documents contain the requirements the DR owner must meet with regards to information exchange as well as the applicable operating agreements.

5.0 Site specific conditions and capacity limitations

During the preliminary stage of DRIP, any limitations regarding the proposed interconnection will be determined. Also, any additional system upgrades required that will be the responsibility of the DR owner will be determined as well.

Under certain circumstances, Manitoba Hydro may limit the size of the DR system in order to maintain the distribution system within all applicable regulations.

6.0 Distribution system characteristics

6.1 General

Manitoba Hydro's distribution system is typically predominantly a three phase, wye connected system. Distribution system voltages (below 50kV) include, but are not limited to, 4.16/2.14kV, 12.47/7.2kV, 24.00/13.85kV, and 24.94/14.40kV.

6.2 Voltage

CSA Standard CAN3 C235.83 – "Preferred Voltage Levels for AC Systems 0 to 50,000V" defines the preferred utilization voltage levels for normal and extreme operating conditions. For systems interconnected above 1000V, the CSA steady state voltage requirement is ± 6%. For systems interconnected below 1000V, Manitoba Hydro will attempt to provide a voltage supply within the levels outlined in Table 3 of CAN3 C235.83.

6.3 System frequency

The Manitoba Hydro interconnected system normally operates at 60 ± 0.2 Hz. A deviation from 60Hz of approximately 0.5 Hz will cause separation of the Manitoba Hydro system from the North American grid. A large disturbance that results in the loss of all tie lines may result in frequency variations of –2.0 to +3.5 Hz. These events are rare, however, they may last up to 10 seconds. Following such an event, one can expect a period of 10 to 15 minutes during which the frequency variation may be of the order of ± 0.1 Hz.

6.4 Harmonics and flicker

Manitoba Hydro's power quality specification, PQS2000-01, describes system characteristics related to harmonics and voltage flicker. Part 1 entitled "Waveform Distortion", addresses harmonics, and part 2, entitled "Voltage Fluctuations", addresses flicker.

6.5 Voltage regulation

Manitoba Hydro's distribution system may or may not have voltage regulation devices installed at the station or downstream of the station.

6.6 Voltage unbalance

The Manitoba Hydro distribution system is a 3 phase system that incorporates single phase loads (taps). This results in voltage unbalance, which under normal operating conditions, may reach 5.0% in rural areas and 4.0% in urban areas. Voltage unbalance is calculated using:

$$\%unbalance = \frac{Highest\ deviation\ from\ the\ average\ of\ the\ 3\ phases}{Average\ voltage\ of\ the\ 3\ phases}$$

6.7 Voltage transients

A Power Quality Assessment of the distribution system in the immediate vicinity of the interconnection can be provided by Manitoba Hydro upon request.

6.8 Fault levels

Fault levels and maximum available fault currents vary considerably throughout the Manitoba Hydro distribution system. These levels must be considered in the design of the utility/DR interconnection. The DR owner must obtain these levels from Manitoba Hydro and use them in the evaluation of equipment selected.

6.9 Grounding

Manitoba Hydro's distribution facilities are normally operated as (but not limited to) effectively grounded and grounded-wye connected sources at the distribution substation secondary bus.

6.10 Phasing

The phase sequence and direction of rotation must be coordinated between the DR owner and Manitoba Hydro during the design phase of the installation.

6.11 Automatic reclosing

The distribution system uses automatic reclosing as part of its overall protection scheme. The DR owner must take this into careful consideration when designing interconnection protection for the DR facility. During fault situations, it is important that the generator is disconnected from the distribution system prior to the first automatic reclose. System protection settings will be reviewed and addressed on a case by case basis. The DR owner must obtain all relevant system protection settings from Manitoba Hydro.

6.12 Automatic source transferral

Some parts of the Manitoba Hydro distribution system are „networked'. A networked distribution system is energized from two (or more) sources simultaneously. Also, for reliability purposes, some areas are supplied by two or more feeders, which can automatically transfer at any given time. From the perspective of the DR facility, interconnecting into a networked system, or systems capable of source transferring, requires the same consideration as automatic reclosing, i.e., isolation of the DR facility must occur whenever there exists the possibility of out-of-phase switching.

6.13 Abnormal conditions

The generator shall take into account the possibility of system disturbances such as frequency and voltage variations when designing the protection scheme for the interconnection.

7.0 Requirements for the interconnection system

7.1 General

Manitoba Hydro has a process for dealing with customer interconnections titled "Distribution Resource Interconnection Process" (DRIP) Within DRIP, there are 5 types of DR interconnections defined:

Type 0 - Non-Parallel Operation (break-before-make)
This type of interconnection uses an open transition transfer switch to connect a standby generator to existing load.

Type I - Momentary transition (<100ms)
This type of interconnection uses a closed transition transfer switch to momentarily connect a standby generator to the utility. This is commonly used to start and test standby generators under load without taking a momentary outage.

Type II - Load displacement (non-export)
This DR interconnection operates in parallel with the utility for the purpose of displacing local load. The DR capacity is less than the total load and power is not allowed to flow in reverse to the utility. Sometimes, load is displaced only during periods of peak demand, known as „peak shaving'.

Type III - Load displacement and export
It is similar to Type II except that power is allowed to flow back to the utility. The power may be purchased by Manitoba Hydro through its Open Access Interconnection Tariff (OAIT). A bi-directional revenue approved meter is required for all type III interconnections.

Type IV - Export only (IPP)
This is a DR facility designed solely for the export of power onto the grid. It may be purchased by Manitoba Hydro or sold into the USA market using Manitoba Hydro's Open Access Transmission Tariff (OATT).

The customer must supply Manitoba Hydro with the following preliminary information regarding the installation:

- type of DR (e.g., synchronous generator, induction generator, direct energy converter)
- fuel source (e.g., diesel, natural gas, solar, wind, fuel cell)
- apparent power rating (KVA)
- real power rating (KW)
- interconnection voltage
- operating capability of equipment (see section 7.0 above)

If the installation falls within the scope of this specification, Manitoba Hydro requires more detailed information prior to installation including:

- a single line diagram and schematics sealed by a Professional Engineer registered in the Province of Manitoba
- generator short circuit level and impedance
- detailed description of the protection scheme
- proposed commissioning tests

At some point, the customer must obtain all necessary system information to complete the design, including fault level at the PCC. Other items are discussed in detail in Section 6 of this specification. Manitoba Hydro will provide this information upon request.

If the information meets the requirements of this specification, Manitoba Hydro will deem the design acceptable and construction can proceed.

7.2 Power quality

7.2.1 Harmonics

The generating facility shall meet the requirements of Manitoba Hydro's Power Quality Specification PQS2000-01.

7.2.2 Flicker

The generating facility shall meet the requirements of Manitoba Hydro's Power Quality Specification PQS2000-01.

7.2.3 Speed regulation

The utility may utilize a synchronous generator to assist in the re-establishment of steady-state system frequency following a system disturbance. See section 7.4.15 for further information.

7.2.4 Voltage regulation and power factor

Manitoba Hydro will define the voltage regulation and power factor requirements on a project by project basis.

The DR owner shall ensure that the voltage levels at the point of interconnection are maintained within CSA 235.83 levels and/or at least equal to the feeder voltage levels, prior to the installation.

Synchronous generators must be equipped with excitation controllers capable of controlling voltage. The generator-bus voltage setpoint shall be stable at, and adjustable to, any value between 95% and 105%.

Induction generators consume reactive power (VARS). As a result, the generator must provide reactive compensation to correct the power factor to ±0.90 or better at the PCC.

Inverters and static power converters must also be capable of adjusting its power factor to ±0.90 or better at the PCC.

7.2.5 Voltage unbalance

The phase-to-phase voltage unbalance must not exceed 1.0%, measured at no-load and with 3-phase balanced loading.

If multiple single phase units are installed, they must be balanced across all 3 phases.

7.2.6 Resonance and self excitation

The potential effects of resonance should be considered as part of the design of the generating facility. This includes:

- Ferro-resonance in the transformer
- Sub-synchronous resonance due to the presence of capacitor banks
- Harmonic resonance with other customers when capacitors are being added as part of the installation

When induction generators are used, the potential for self excitation should be assessed and addressed.

7.2.7 DC current injection

As per PQS2000-01, Manitoba Hydro does not allow any DC offset.

7.3 Interconnection

7.3.1 Disconnecting means

A disconnect switch, installed, owned, maintained and operated by Manitoba Hydro, is required on the high side of the interconnection transformer. For 3 phase generating facilities, this switch shall be 3 phase, gang-operated.

For multiple generator facilities, one switch must have the capability of isolating all generators simultaneously.

7.3.2 Interconnection transformer

The transformer winding impacts how system faults are detected and what type of protection is required (see section 7.4). For customer owned transformation, the transformer winding configuration shall be reviewed and approved by Manitoba Hydro prior to installation.

7.3.3 Grounding

Grounding of the interconnection shall be designed to provide;

- Solidly grounded distribution facilities
- Fault detection that isolates all sources of fault contribution including the generator or distribution system

- Protection of the low voltage side from damage due to high fault currents

7.3.4 Phasing and phase sequence

The phase sequence and direction of rotation shall be compatible with the Manitoba Hydro system.

7.3.5 Interrupting device

An interrupting device shall be provided by the DR owner and be located in an area agreed upon with the DR owner and Manitoba Hydro which is accessible by Manitoba Hydro staff to operate in emergency conditions.

7.4 Interconnection protection

7.4.1 General

There are 2 conditions for which the DR facility protection must be designed for:

1. faults that occur within the DR facility
2. de-energization of the Manitoba Hydro distribution system

The utility system can become de-energized by one of the following:

- faults on the distribution system, including 3 phase, line-to-ground and line-to-line, that cause Manitoba Hydro's system protection to operate.
- manual operation of the distribution protective devices (ACR, breaker, etc.) for testing or maintenance purposes
- open phase(s) or loss-of-phase scenarios due to blown fuses or conductors breaking

The purpose of the protection scheme is to reduce the risk of equipment damage and maintain reliability of supply and must include both protective and permissive functions. It can be separated into 3 sections:

i) Generator source protection (GSP)
ii) Synchronization protection (SP)
iii) Utility source and anti-Islanding protection (USP)

The GSP protects the generator from internal faults, loss of excitation, reverse power and frequency excursions. The SP includes a synchronizer as well as under/over frequency and voltage relays connected across the transfer switch. The purpose of the USP is to protect the DR facility from system faults, to prevent reverse power flow into the utility and prevent islanding.

A complete list of typical protection requirements are presented in Appendix B at the end of this document. Appendix C shows examples of typical protection schemes for different transformer configurations. From a utility perspective, these schemes represent the minimum requirements. However, it is up to the customer to prove that their particular scheme will work.

The protection scheme shall be designed to detect the following conditions at the PCC:

a) Balanced and unbalanced system faults (i.e. line-ground, line-line, and three phase faults)
b) Frequency variations
c) Voltage variations
d) Islanding conditions

Depending upon location, the protection scheme may be required to detect additional conditions such as open phase, ferro-resonance, negative sequence voltage, or zero sequence currents.

The protection scheme must fully coordinate with any existing distribution system protective devices. The DR owner must submit a complete protection design package including all relay settings, tripping schemes and schematics to Manitoba Hydro for review and approval prior to installation. Both existing and infinite bus fault levels should be considered.

The point of measurement for voltage and frequency shall be at the PCC or POI as agreed upon with Manitoba Hydro.

7.4.2 Device ratings

All fault current interrupting devices must be adequately sized to account for fault contributions from the generating facility and the interconnected distribution system. Manitoba Hydro will provide the present and anticipated (future) fault contributions from the distribution system. All relaying devices shall be subject to approval by Manitoba Hydro.

7.4.3 Minimum protection requirements

The following shall be provided for all Type III and Type IV interconnections
a) under-voltage
b) over-voltage
c) under-frequency
d) over-frequency
e) overcurrent

Additional protection requirements are dependant upon the transformer configuration and the distribution system characteristics. Type II interconnections may not require all items listed above and minimum requirements will be specified for each interconnection by Manitoba Hydro. See section 7.4.13 for minimum requirements for Type I interconnections.

7.4.4 Phase and ground fault protection

The DR facility protection must be able to detect the following:

- fault between phases,
- fault between phase(s) and ground

both within the customer's facility and on the Manitoba Hydro distribution system.

7.4.5 Open-phase condition

The DR facility protection must be capable of detecting the loss of any phase to which the DR system is connected both within the DR system and the Manitoba Hydro distribution system.

7.4.6 Over-frequency/under-frequency protection

The DR facility must be equipped with over/under frequency protection that meets the requirements of Table 7.4.1.

Minimum Time	Under frequency Limit	Over frequency Limit
(continuous operating range)	59.0 – 60.0 Hz	60.0 – 61.5 Hz
10 minutes	58.7 – 58.9 Hz	61.6 – 62.0 Hz
30 seconds	58.0 – 58.6 Hz	62.1 – 63.5 Hz
instantaneous trip	Less than 58.0 Hz	Greater than 63.5 Hz

Table 7.4.1

7.4.7 Under-voltage/over-voltage protection

The generating facility protection must have the ability to detect voltage (measured phase to ground) that is outside the normal operating limits of 90% < V < 106% of nominal and trip the generator breaker within the trip times shown in Table 7.4.2.

PU Voltage	Trip Time
V ≤ 50%	Instantaneous
50% < V < 90%	120 cycles
90% < V < 106%	Normal Operation
106% < V < 120%	30 cycles
V ≥ 120%	Instantaneous

Table 7.4.2

7.4.8 Anti-islanding protection

Unless agreed upon by Manitoba Hydro, generating facilities shall not be permitted to remain connected to a de-energized distribution system, i.e., islanding is not usually allowed. As a result, Manitoba Hydro requires anti-islanding protection (**AIP**) at the point of interconnection between the DR facility and the Manitoba Hydro distribution system regardless of whether intentional islanding is allowed. The cost for this protection will be the customer's responsibility.

The reasons for having AIP are;

- to avoid out-of-phase reclosing between Manitoba Hydro and the DR facility
- to prevent safety hazards created as a result of back feeding isolated portions of the Manitoba Hydro system
- to add redundancy to generator protection internal to the DR facility

The level of anti-islanding protection depends on the type of DR that is interconnected. The following tables outline Manitoba Hydro's requirements for anti-islanding protection as well as how the location of the anti-islanding protection is determined.

Generating Mode	Existing Feeder Protection	Anti-Islanding Protection Requirement
Not exporting to Manitoba Hydro	3 phase reclosing device with ground trip detection and sufficient feeder load*	Reverse power relay (32) at the point of common coupling
	3 phase reclosing device with no ground trip detection, or 3 individual single phase reclosing devices	Reverse power relay (32) and zero sequence voltage protection at the point of common coupling
Exporting to Manitoba Hydro	N/A	Transfer trip signal between Manitoba Hydro breaker or recloser and DR facility

Table 7.4.3

*IEEE 1547 considers feeder load to be sufficient if the total generator capacity is less than 33% of the feeder load.

Facility Supply Transformer Winding	Anti-Islanding Protection Location
Delta primary, grounded-wye secondary	Zero sequence protection must be located on the primary side. Reverse power can be either on the primary or secondary side of the transformer.
Grounded-wye primary, grounded-wye secondary	Protection can be installed on either the primary or secondary side of the transformer
Other winding configurations	Will be looked at on a case-by-case basis

Table 7.4.4

7.4.9 Transformer winding configuration

The transformer winding configuration will have an impact on the location and level of protection required for the DR interconnection. See Appendix B for examples for typical synchronous generator protection schemes for different transformer configurations.

7.4.10 Inadvertent energization

Unless islanding is specifically allowed by Manitoba Hydro, the DR system shall not be capable of energizing the distribution system when the distribution system is de-energized.

7.4.11 Conditions for connecting to an energized distribution system

The generating facility may be reconnected once the system has stabilized and the RMS voltage has returned to normal levels for a minimum of **5 minutes**.

7.4.12 Transfer trip specification

For specific interconnections where Manitoba Hydro specifies that a transfer trip scheme is required, Manitoba Hydro will provide the distribution system minimum operating time for the distribution protection equipment.

7.4.13 Momentary closed transition switching

Anti-islanding protection is not required for DR systems that are parallel with the distribution system for less than 100ms. The transfer switch must be CSA approved. The DR owner must demonstrate the 100ms transition switching capability of the system to Manitoba Hydro before being approved for operation. Under-voltage protection and a manual or automatic synchronization check are required.

7.4.14 Synchronization

7.4.14.1 General

Any generating device that is able to generate voltage while disconnected from the distribution system requires synchronization facilities before connection is permitted. The DR system shall maintain synchronization with the

Manitoba Hydro distribution system while operating in parallel. The generating facility has the responsibility of maintaining synchronization with the Manitoba Hydro system. Manitoba Hydro cannot synchronize to the generating facility. Any proposed synchronizing scheme must be submitted to Manitoba Hydro, prior to the installation. It must be able to accommodate automatic re-closing of the distribution feeder.

Paralleling of the DR and the distribution system shall not cause voltage fluctuations outside of the Manitoba Hydro flicker criteria.

7.4.14.2 Synchronous generators

Connection shall be prevented when the generating facility and/or the Manitoba Hydro distribution system is operating outside of the following limits:

Total Generation	Frequency Difference	Voltage Difference	Phase Angle Difference
0 – 500 KVA	0.3 Hz	10%	20°
>500 – 1500 KVA	0.2 Hz	5%	15°
>1500 KVA	0.1 Hz	3%	10°

Table 7.4.5

Operation of the interconnection shall not cause voltage fluctuations outside of the Manitoba Hydro flicker criteria.

7.4.14.3 Induction generators

Induction generators that act as motors during start-up, do not require synchronization facilities. Paralleling or disconnection of the DR and the distribution system shall not cause voltage fluctuations outside of the Manitoba Hydro flicker criteria.

7.4.14.4 Inverter-based DR

Inverter-type or line-commutating voltage following equipment does not require synchronization facilities. Operation of the interconnection (or disconnecting of the DR facility) shall not cause voltage fluctuations outside of the Manitoba Hydro flicker criteria.

7.4.15 Speed regulation versus anti-islanding

The use of speed regulation with system frequency as a reference may be required for larger synchronous generator DR systems (generally above 1MW). In such cases, Manitoba Hydro shall provide the DR owner with its requirements.

A transfer trip function may be required for DR systems operating with a speed regulation system in areas where islanding is not allowed. Speed control shall be disconnected during synchronization between the DR system and Manitoba Hydro.

7.4.16 Monitoring and information exchange

In certain locations or for certain sizes of DR systems, the DR owner may be required to provide Manitoba Hydro with real time information regarding connection status, real and reactive power output, and voltage at the POI. The communication protocol and the equipment required will be specified by Manitoba Hydro.

Whenever any protective device within the DR system operates, the protection scheme shall log which protective operations occurred and the status of the DR during the operation including power output, voltage, and current.

If it is determined that the DR system may have an impact on Manitoba Hydro's Transmission Network, the DR owner will be required to provide a Remote Terminal Unit (RTU) or Data Link to a Manitoba Hydro RTU capable of exchanging SCADA information with the Manitoba Hydro System Control Centre. The protocol for data exchange via the RTU shall be compatible with that used for communications by the System Control Centre. Manitoba Hydro will provide the DR owner with the protocol for data exchange.

As a minimum, the DR Owner is required to provide the following data needed by the Supervisory Control and Data Acquisition (SCADA) system:

- Hourly integrated billing MWh,
- Hourly integrated MVARh,
- Individual generator(s) MW and MVAR, where identified,
- Generator(s) breaker status,
- Individual generator on/off status, if no generator breaker exists,
- Total station instantaneous MW and MVAR,
- Station service instantaneous MW, MVAR, hourly MWh and MVARh,
- Generator transformer(s) high voltage side breaker(s) and isolator(s) status,
- Bus voltage at high voltage bus,
- PSS status, if applicable,
- AVR status, if applicable,
- AVR voltage setpoint, if requested,
- Total plant MW setpoint, if requested,
- Instantaneous ambient temperature, if requested,
- Generator step-up transformer tap setting, if requested.

(SCADA readings shall be taken in four (4) second intervals.)

7.4.17 Electromagnetic interference (EMI)

The influence of EMI shall not affect the operation of the DR facility protection. The protection scheme shall comply with either CAN/CSA-CEI/IEC 61000-4-3 or IEEE C37.90.2 and the DR owner shall provide documentation of compliance to Manitoba Hydro.

7.4.18 Surge withstand

The protection equipment must meet the surge withstand requirements of IEEE/ANSI C62.41 or C37.90.1.

7.4.19 Batteries and auxiliaries

Batteries and auxiliaries shall have sufficient capacity to ensure the operation of all protection functions during loss of supply. The protection functions must remain operational for at least 10 minutes.

7.4.20 Protection scheme failure

If the interconnection protection system or breaker trip coil fails or the auxiliary supply is lost, the DR system shall isolate from the Manitoba Hydro system instantaneously.

If the transfer trip communication fails, the DR system shall isolate from the Manitoba Hydro system within the time specified by Manitoba Hydro as per section 7.4.12.

In the event of a loss of supply or a loss of the DR protection scheme, the generating facility may be reconnected once the system has stabilized and the RMS voltage has returned to normal levels for a minimum of 5 minutes.

The DR owner shall provide satisfactory evidence to Manitoba Hydro that the protection scheme failure mitigation has been incorporated in the design of the system.

Protection functions shall remain operational following distribution system disturbances or loss of supply for a period of 10 minutes.

7.4.21 Instrument transformers used for protection

Instrument transformers used for protection must comply with CAN/CSA-C60044-6 or IEEEC57.13.

8.0 Interconnection tests

8.1 General

The tests specified in section 8 shall apply to all interconnection systems. Manitoba Hydro reserves the right to specify which tests will be required prior to interconnection.

8.2 Type tests

8.2.1 General

Type tests shall be performed in accordance with sections 8.2.2 through 8.2.11. For multiple protection schemes, each specific scheme will require testing.

8.2.2 Temperature stability

The DR interconnection system equipment shall operate within the manufacturer's specified temperature range as specified in section 5.1 of IEEE 1547.1.

8.2.3 Response to abnormal frequency

The DR interconnection system equipment shall cease to energize the interconnection under the abnormal frequency conditions specified in Table 7.4.1 when tested in accordance with section 5.3 of IEEE 1547.1.

8.2.4 Response to abnormal voltage

The DR interconnection system equipment shall cease to energize the interconnection under the abnormal voltage conditions specified in Table 7.4.2 when tested in accordance with section 5.2 of IEEE 1547.1.

8.2.5 Synchronization

The DR interconnection system shall synchronize the interconnection with the utility as specified in Table 7.4.3 when tested in accordance with section 5.4 of IEEE 1547.1.

8.2.6 Interconnection integrity

The DR interconnection system shall meet the surge withstand requirements specified in section 7.4.18 when tested in accordance with section 5.5 of IEEE 1547.1.

8.2.7 Unintentional islanding

Where Manitoba Hydro requires anti-islanding protection or minimum import power levels, the DR system shall cease to energize when tested in accordance with section 5.7 of IEEE 1547.1.

8.2.8 Open phase

The DR interconnection system shall cease to energize the interconnection with the utility upon the loss of an individual phase on the distribution system when tested in accordance with section 5.9 of IEEE 1547.1.

8.2.9 Reconnect following abnormal condition disconnect

The DR interconnection system shall not allow interconnection with the utility following operation of the protection system as specified in section 7.4.11 when tested in accordance with section 5.10 of IEEE 1547.1.

8.2.10 DC injection (for inverters without interconnection transformers)

The DR interconnection system shall comply with section 7.2.7 when tested in accordance with section 5.6 of IEEE 1547.1.

8.2.11 Harmonics

The DR interconnection system shall comply with section 7.2.1 when tested in accordance with section 5.11 of IEEE 1547.1.

8.3 Production tests

8.3.1 General

Production tests shall be performed in accordance with sections 8.3.2 through 8.3.4. For DR equipment with multiple set points, a single series of set points specified by the manufacturer can be used for testing. Production tests may take place at the factory or on site as part of commissioning tests.

8.3.2 Response to abnormal frequency

The DR interconnection system equipment shall cease to energize the interconnection under the abnormal frequency conditions specified in Table 7.4.1 when tested in accordance with section 6.2 of IEEE 1547.1.

8.3.3 Response to abnormal voltage

The DR interconnection system equipment shall cease to energize the interconnection under the abnormal voltage conditions specified in Table 7.4.2 when tested in accordance with section 6.1 of IEEE 1547.1.

8.3.4 Synchronization

The DR interconnection system shall synchronize the interconnection with the utility as specified in Table 7.4.3 when tested in accordance with section 6.3 of IEEE 1547.1.

8.4 Verification of interconnection systems (commissioning tests)

8.4.1 General

Commissioning tests shall take place during or following installation of the DR interconnection system and must be coordinated with Manitoba Hydro.

Commissioning test procedures should be specified by the manufacturer or interconnection system integrator. Manitoba Hydro requires a representative shall be present during all or a portion of the tests specified in section 8.4.

8.4.2 Interconnection verification and specifications

Manitoba Hydro may specify that some or all of the following verifications and inspections take place:

a) Final DR interconnection system protection settings shall be presented to and verified by a Manitoba Hydro representative.
b) Visual inspection shall ensure that grounding requirements specified in 7.3.3 have been met.
c) Visual inspection shall confirm the presence of a disconnecting means in accordance with 7.3.1.
d) The polarities, burdens, and ratios of field wired instrument transformers shall be verified as correct and in accordance with the design.
e) Field installed power and control wiring shall be verified to be in compliance with the drawings and manufacturers requirements.
f) For three-phase installations, the phase rotation of the distribution system and the DR system as installed shall be verified as compatible.
g) All monitoring and information exchange provisions shall be verified as functional in accordance with 7.4.16.
h) Calibration checks of the protective relays shall be performed.
i) Functionality of the protective relays, circuit breakers, and telecommunications equipment shall be tested to verify that they operate as a system.
j) Load tests of protective relays shall be conducted immediately after initial energization, where applicable.
k) The ohmic value and connection of the transformer neutral impedance grounding device shall be verified as correct.
l) It shall be verified that upon loss of power supply to the DR interconnection, the protection scheme activates the interconnection circuit breaker.
m) It shall be verified that upon loss of communication signal, a fail-safe transfer trip occurs when required as in 7.4.12.

8.4.3 Disconnecting means operability

The disconnecting means specified in 7.3.1 shall be verified as operational.

8.4.4 Energization cessation

Tests shall be conducted in accordance with section 7.5 of IEEE 1547.1 to verify the functionality of the protection that ensures the cessation of energization of the distribution system under the following conditions:

a) abnormal frequency as specified in 7.4.6;
b) abnormal voltage as specified in 7.4.7;
c) protection scheme failure as specified in 7.4.20; and
d) additional protection functions required as specified in 7.4.3.

Where a reverse power or minimum power function is used to meet interconnection requirements, it shall be tested using secondary injection techniques, by using a local load trip test, or by adjusting the DR output and local loads to verify that the applicable non-export criteria are met.

8.5 Maintenance

The DR owner shall maintain the facilities in accordance with Rule 2-300 of the Canadian Electrical Code to ensure safe parallel operation with the Manitoba Hydro system. Manitoba Hydro reserves the right to periodically inspect the interconnection protection system to verify that it is still valid.

8.6 Installation modification

The DR owner shall obtain approval from Manitoba Hydro prior to making any changes to the DR system or the protection scheme. If the change requires the installation or modification of equipment, the DR owner shall provide documentation that the new equipment meets the requirements of 8.2 and 8.3.

Appendix A

Primary References

IEEE Draft Standard P1547
"Draft Standard for Interconnecting Distributed Resources with Electric Power Systems", August 2001

CSA C22.3 No. 9-08
"Interconnection of distributed resources and electricity supply systems"

University of Wisconsin, Dept. of Engineering Professional Development, Course Notes
"Interconnecting Distributed Generation to Utility Distribution Systems", May 2002

Manitoba Hydro PQS2000-01
"Power Quality Specification for Connection to the Manitoba Hydro Electrical System, Part 1: Waveform Distortion", November 2000

Manitoba Hydro PQS2000-02
"Power Quality Specification for Connection to the Manitoba Hydro Electrical System, Part 2: Voltage Fluctuations", August 2002

Manitoba Hydro
"Technical Requirements for Facility Connection to the Manitoba Hydro Interconnected Transmission System Generally at 60 KV and Above"

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

IEEE Std. 493-1900 IEEE Recommended Practice for Design of Reliable Industrial and Commercial Power Systems (IEEE Gold Book). Chapter 9 deals specifically with voltage sags analysis and methods of reporting sag characteristics graphically and statistically.

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

IEEE Std. 1100-1992 IEEE Recommended Practice for Powering and Grounding Sensitive Electronic Equipment (IEEE Emerald Book).

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

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

The following standards are applicable to the interconnection of distributed resources on the utility system:
Canadian Electrical Code, CSA no. C22-1, latest version

C22.2 No. 31- M89 (R1995) - Switchgear Assemblies

Can/CSA - C22.2 No. 107.1- 95 - Commercial and Industrial Power Supplies

Can/CSA - C22.2 No. 1010.1 -92 - Safety Requirements For Electrical Equipment for Measurement, Control and Laboratory Use

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

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

C22.2 No. 201-M1984 (R1992) - Metal Enclosed High Voltage Busways

C22.2 No. 229-M1988 (R1994) - Switching and Metering Centres

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

IEEE Std. 100 - 1997 IEEE Standard Dictionary of Electrical and Electronics Terms

IEEE Std 315-1975 (Reaffirmed 1993) ANSI Y32.3-1975 (Reaffirmed 1989) CSA Z99-1975 Graphic Symbols for Electrical and Electronics Diagrams (Including Reference Designation Letters)

IEEE Std 929-1988 IEEE Recommended Practice for Utility Interface of Residential and Intermediate Photovoltaic (PV) Systems

C37.1 ANSI/IEEE Standard Definitions, Specifications and Analysis of Systems Used for Supervisory Control, Data Acquisition, and Automatic Control

C37.2 IEEE Standard Electrical Power System Device Function Numbers

C37.18 ANSI/IEEE Standard Enclosed Field Discharge Circuit Breakers for Rotating Electric Machinery

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

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

C37.24 ANSI/IEEE Standard for Radiation on Outdoor Metal-Enclosed Switchgear

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

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

C37.50 ANSI Standard Test Procedures for Low-voltage AC Circuit Breakers Use In Enclosures

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

C37.52 ANSI Standard Test Procedures for Low-voltage AC Power Circuit Protectors Used in Enclosures

C57.12 IEEE Standard General Requirements for Liquid Immersed Distribution, Power and Regulating Transformers

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

C57.13.1 IEEE Guide for Field Testing of Relaying Current Transformers

C57.13.2 IEEE Standard Conformance Test Procedures for Instrument Transformers

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

C37.90 ANSI/IEEE Standard for Relays and Relay Systems Associated with Electric Power Apparatus

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

C37.90.2 ANSI/IEEE Standard Withstand Capability of Relay Systems to Radiated Electromagnetic Interference from Transceivers

C37.95 IEEE Guide for Protective Relaying of Utility Consumer Interconnections
C37.98 ANSI/IEEE Standard for Seismic Testing of Relays

UL1008 Transfer Switch Equipment

Measurement System Standard / Transmission Administrator Metering Standard GC301 Practices for Management and Transfer of Metered Data

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

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

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

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

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

C37.012-1979 (R1988) IEEE Application Guide for Capacitance Current Switching for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis

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

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

C37.081-1981 (Reaff 1988) Guide for Synthetic Fault Testing of AC High-Voltage Circuit Breakers Rated on a Symmetrical Current basis

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

C37.81-1989 (R1992) IEEE Guide for Seismic Qualification of Class 1E Metal-Enclosed Power Switchgear Assemblies

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

ANSI/IEEE C37.90-1989 - Surge Withstand And Fast Transient Tests

120-1989 (Reaff-1997) IEEE Master Test Guide for Electrical Measurements in Power Circuits

1291-1993 IEEE Guide for Partial Discharge Measurement in Power Switchgear
IEEE Std C62.23-1995 - Application Guide for Surge Protection of Electric Generating Plants

ANSI /IEEE C62.41-1991 - Recommended Practices on Surge Voltages in Low Voltage AC Power Circuits

C57.13-1993 IEEE Standard Requirements for Instrument Transformers

C57.13.3-1983 (R1991) IEEE Guide for the Grounding of Instrument Transformer Secondary Circuits and Cases

C57.98-1993 IEEE Guide for Transformer Impulse Tests

C57.19.100-1995 (R1997) IEEE Guide for Application of Power Apparatus Bushings

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

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

IEEE Std 242-1986 Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems

ANSI C12.20 - Electricity Meters 0.2 And 0.5 Accuracy Classes

ANSI C62.1 - Surge Arresters for AC Power Circuits

ANSI C62.11 - Metal-Oxide Surge Arresters for AC Power Circuits

NEMA CC-1 - Electric Power Connectors for Substations

NEMA LA-1 - Surge Arresters

NEMA MG-1 – Motors

Appendix B

Single phase protection requirements (50kW or less)

Device	Description
89	Interconnect disconnect device
89G	Generator disconnect device
59T	Over voltage trip
27	Under voltage trip
81O/U	Over/Under frequency trip
50/51	Overcurrent trip
25	Synchronizing check*

*Applies to synchronous and other types of single phase generators with standalone capability.

Typical three phase DR protection requirements.

Device	Description	AIP	USP	SP	GSP
TT	Transfer trip (note 2)	O			
59G	Ground overvoltage (note 3)	X			
32	Reverse power (note 4)	X	X		X
27	Under voltage trip	X	X	X	X
59	Over voltage trip		X	X	X
46	Negative sequence overcurrent (note 5)	O	X		
47	Negative sequence voltage	O	X		
67	Directional overcurrent (note 7)	O	O		
51	Overcurrent		X		X
51G	Neutral overcurrent (note 5)		O		
51V	Voltage controlled overcurrent (note 6)		O		
59I	High speed overvoltage (note 8)		O		
59T	Time overvoltage		X		
25	Synchronization check			X	
40	Loss of excitation				X
81O	Over frequency		X	X	X
81U	Under frequency		X	X	X
89	Interconnect disconnect device	X	X		
89G	Generator Disconnect Device				X

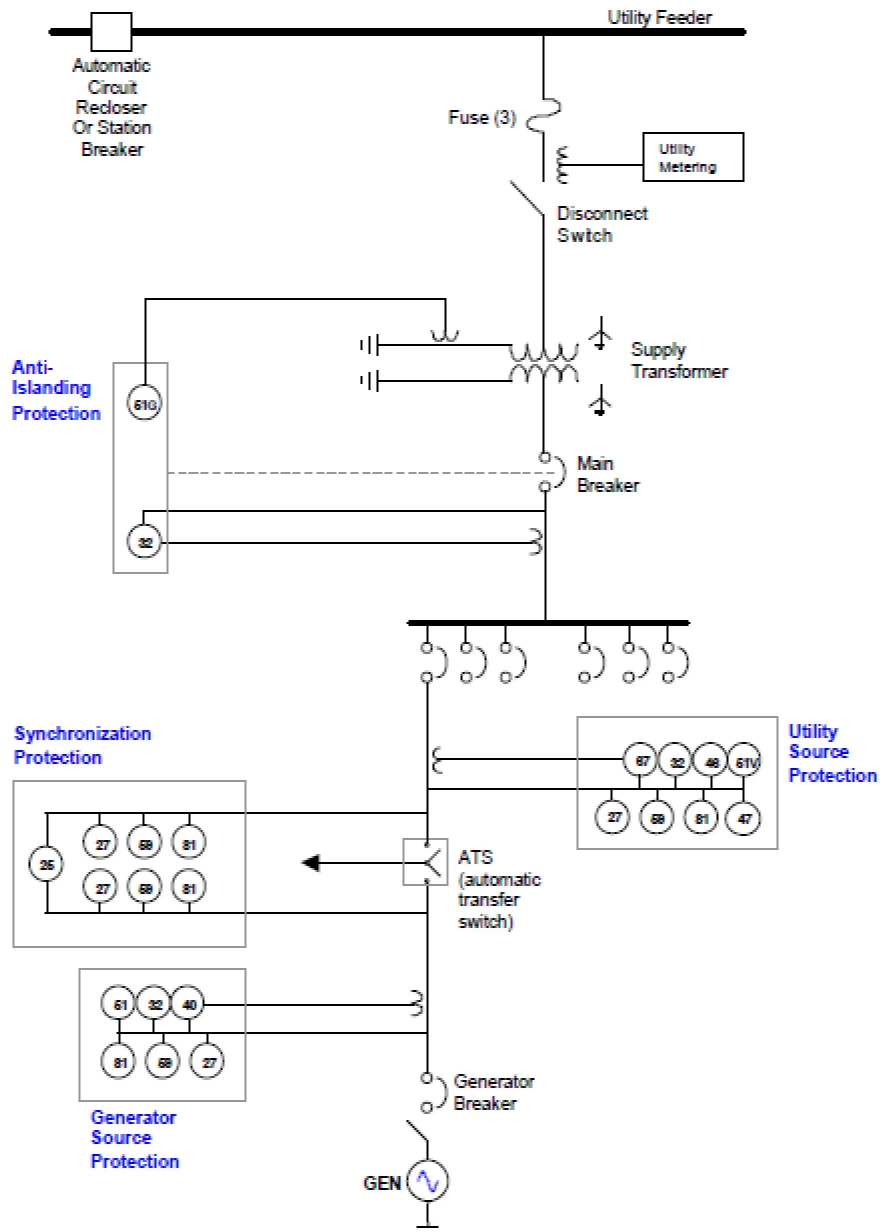
AIP=anti-islanding protection, USP=utility source protection, SP=synchronization protection, GSP=generator source protection

Notes:

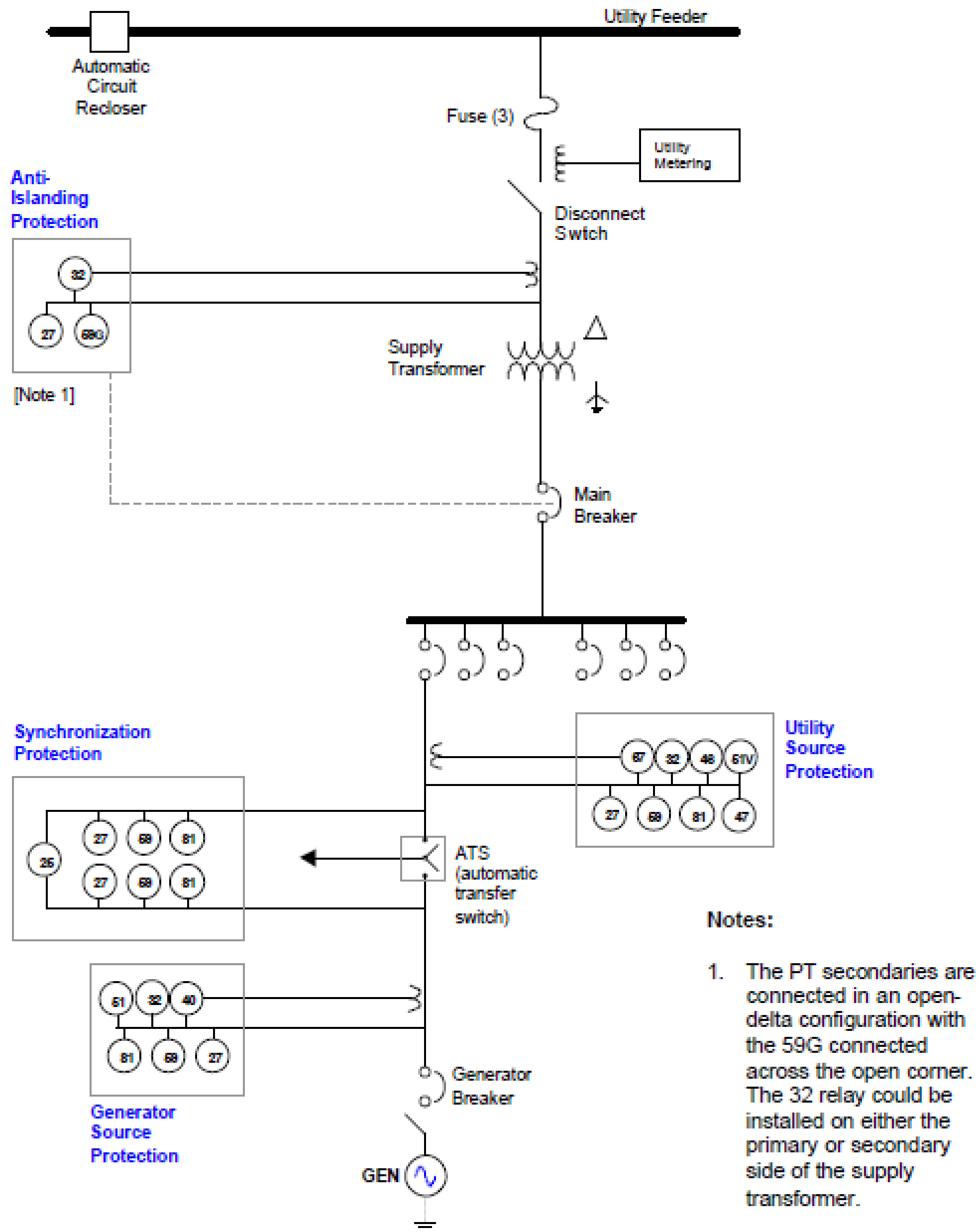
1. Items marked „X' are required, „O' are optional. These are typical requirements. The DR owner is free to use alternative methods provided they can be shown to work.
2. Transfer trip required only when DR is exporting to Manitoba Hydro.
3. Used as part of a primary-connected, open delta pot arrangement to detect feeder faults and prevent islanding when utility/DR interface transformer is delta-grounded wye. Not required for grounded-wye/grounded-wye transformation.
4. Used to prevent islanding in the „non-export' mode.
5. Device 46 can be used as an alternative to the 51G relay.
6. Required only if 27 operating time is considered too slow to detect feeder faults.
7. Is sometimes used as an alternative to the 32 relay however it can be more susceptable to nuisance tripping in the presence of capacitance.
8. Used if ferroresonance is expected.

Appendix C

Example of a synchronous generator protection scheme for a grounded-wye, grounded-wye supply transformer



Example of a synchronous generator protection scheme for a delta, grounded-wye supply transformer



Note: Acceptable protection schemes are not limited to the examples listed. Any engineered protection scheme which meets all the requirements set out in the Engineering Study may be approved for interconnection.

Appendix D
Protection Relay Nomenclature

Relay	Function
TT	Transfer trip; this is a signal established between a utility protective device and the DR facility protection. The purpose is to ensure that the DR facility is isolated whenever the utility protective device operates. The signal can be over cable or radio frequency.
59G	Ground overvoltage; if connected across an open delta pot bank arrangement, it can be used to detect zero sequence voltage generated by system disturbances and faults.
32	Power direction: used to detect reverse power
27	Under voltage trip; detects under voltage and should be set to approximately 90% of normal voltage. The time setting, like the 59T, should be set longer than the normal clearing time of the feeder protection but less than the substation breaker reclosing time. 30 to 60 cycles is a reasonable setting.
59	Overvoltage trip
46	Negative Sequence Current; an alternative to the 51N, used to detect transformer overloads due to unbalanced feeder loads.
47	Negative sequence voltage; used for permissive operation to avoid closing the generator into a single phased bus.
67	Directional overcurrent; The 67 relay is used to detect reverse power flow and is more reliable than a 32 relay during system faults. However, may result in nuisance tripping due to leading current created by local capacitors.
51	Overcurrent; set to coordinate with the DR generator protection and any protection on the local load.
51V	Voltage Controlled Overcurrent; used for fast tripping for feeder faults. 27 will also operate, but must be delayed by 30 to 60 cycles.
59I	High Speed Overvoltage; detects ferroresonance or high overvoltages that may occur during islaning conditions.
59T	Time Overvoltage; used to detect backfeeding the feeder from the DR during an islanding condition. The voltage elements are set to 110% of normal voltage. The time setting should be set less than the normal substation breaker reclosing time, but, preferably longer than the normal clearing time of the feeder protection, to avoid nuisance operations for faults on adjacent feeders. 30 to 60 cycles is a reasonable setting.
25	Synchronism Check; monitors the correct closing of the generator breaker.
40	Loss of excitation
81O/U	Over and Under Frequency; faster than the 27 and 59T.
51N	Neutral Overcurrent; measures zero sequence current flowing through the transformer. If the generator neutral is solidly grounded or grounded through an impedance, the 51N detects feeder ground faults or feeder load imbalance that could possibly overload the transformer. Alternative schemes would be to apply a low set negative sequence overcurrent relay (46).