

***MicroPower Connect* Interconnection Guideline**

**For inverter based micro-distributed resource (DR) systems
connected to 600 volt or less distribution systems**

Version 8

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Foreword

MicroPower Connect is an initiative supported by Natural Resources Canada through the Climate Change Action Plan 2000 funding. The objective of this initiative facilitated by Electro-Federation Canada is to reduce barriers for the adoption of small inverter-based distributed resources (DR).

This Guideline aims at easing the interconnection of inverter based DR with the existing distribution grids, which were not traditionally designed to accommodate and integrate distributed resources at the distribution level, while avoiding negative impact on system reliability and safety.

This national Guideline is the result of a two year consensus work of the MicroPower Connect Technical Committee representing various stakeholders across Canada, with input from external parties, and is intended to serve as a model for Canadian utilities in the interim of a nationally recognized standard. Requirements of this Guideline are consistent, to the extent possible, with other existing regional and international interconnection guidelines and standards; whenever consistency could not be ensured a note was then added.

This document establishes guidelines for interconnection of micro distributed resources based on inverter technology, forging a way forward for alternative energy sources to become part of the electricity supply mix. It is hoped that this path will benefit other technologies that follow enabling micro DR interconnection.

For any additional information on MicroPower Connect or to provide feedback on this document you may contact:

MicroPower Connect Secretariat
c/o Electro-Federation Canada
5800 Explorer Drive, Suite 200
Mississauga, Ontario L4W 5K9
Tel: (905) 602-5686
Fax: (905) 602-8877
E-mail: info@micropower-connect.org
Web: www.micropower-connect.org

Participants

This Guideline is the result of work by the Technical Committee, with a particular involvement from the Writing Sub-Committee (WSC) members:

Technical Committee:

Peter Baroutis, Toronto Hydro
Mike Bourassa, Standards Council of Canada
Rob Brandon, NRCan / CETC-Ottawa
Liuchen Chang, University of New Brunswick
Patrick Cusack, ARISE Technologies Corporation (WSC)
Loise DeSilva, Standards Council of Canada
Ross Dorward, Dorward Engineering
Per Drewes, Sol Source Engineering
Bert Dreyer, ENMAX (WSC)
Tim Eckel, SaskPower (WSC)
Bill Ellis, Nova Scotia Power (WSC)
Tony Flood, Electro-Federation Canada, TC Chair
Richard Fulton, BC Hydro (WSC)
Gordon Howell, Howell-Mayhew Engineering
John Johnson, Your Energy Company
Brenon Knaggs, Ballard Generation Systems
Eric Le Courtois, Hydro-Quebec / LTE (WSC)
Malcolm Lodge, Island Technologies
Gordon Maher, Manitoba Hydro
Alan Mak, EPCOR (WSC)
Brian Manning, Manitoba Hydro
Sylvain Martel, NRCan / CETC-Varenes, Secretary (WSC)
David Mascarenas, Canadian Standards Association
Gilbert Montminy, Régie du bâtiment du Québec
Joseph Neu, Electro-Federation Canada, Advisory Committee Chair
Mark Romanow, Global Thermoelectric
Etienne Roussel, New Brunswick Power
Brian Savaria, Eaton | Cutler-Hammer
Vince Scaini, Satcon Power Systems

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1.0 PURPOSE

This interconnection application guideline establishes uniform requirements for the interconnection of micro-distributed resource (DR) systems with Distribution Systems.

This Guideline is based on the following assumptions and principles:

- The addition of micro-DR Systems to the Distribution System will not appreciably change the Distribution System and its characteristics.
- The installation meets the installation requirements of the Canadian Electrical Code (CE Code) Part 1 and the equipment is certified to the relevant Part 2 product standard. Other local and provincial construction and installation regulations may apply.
- Safety of personnel, the public and equipment is of primary concern in the design of the interconnection systems. Low voltage micro-generation inverter based systems interconnected with certified products are safe and meet the intent of the rules in the CE Code that were developed for high voltage engineered systems.

2.0 SCOPE & LIMITATIONS

The criteria and requirements are applicable to Micro-DR Systems that use an inverter (single or three phase) between the energy source and the Distribution System to generate ac electricity in parallel with the Distribution System, and have a nominal operating output voltage of 600 volts ac or less connected to a PCC of 600 volts or less. This guideline is not intended to apply to power systems that are momentarily connected through automatic transfer schemes. Additional requirements may apply for interconnection with Network Distribution Systems. This guide may require modification and additions for interconnection of other DR technologies.

Meeting the requirements of this guideline does not constitute approval to connect to the Wires Owner's Distribution System.

3.0 DEFINITIONS AND REFERENCES

3.1 Acronyms and definitions as used in this guideline

3.1.1 Acronyms

ANSI: American National Standards Institute, an organisation with legal authority to approve US National standards.

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

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

UL: Underwriters Laboratory, an accredited standards development organisation within the United States of America.

3.1.2 Definitions

Alternating Current (AC): Electric current that periodically alternates direction of flow and is zero at some time during its period.

Cease to Energize: Cessation of energy outflow capability.

Current Transformer (CT): A device used to transform the current of a circuit to a more useful range and form for measurement or control.

Direct Current (DC): Electric current that flows in one direction.

Distributed Generation (DG): Electric generation facilities connected to a Distribution System through the Point of Common Coupling (PCC). Distributed Generation is a subset of Distributed Resources (DR).

Distributed Resource (DR): Sources of electric power that are not directly connected to a bulk power transmission system. DR includes both generators and energy storage technologies.

Distribution System: Any facilities that operate at a nominal voltage of 34 500 V or less and distribute electric power between substations and PCCs.

Electromagnetic Interference (EMI): A condition where electromagnetic energy interferes with the proper operation of equipment.

Generator: Equipment that produces electric power. The inverter is recognised as being the "generator" as viewed by the Wires Owner distribution facility.

Hertz (Hz): The common unit used to describe periodic event frequency. It is a measure of the number of times or cycles that a periodic signal repeats in a second, also denoted as *cycles per second*.

Interconnection: The result of the process of electrically connecting a DR System in parallel to a Distribution System.

Interconnection System: The collection of all interconnection equipment and functions, taken as a group, used to interconnect a DR unit(s) to the point of DR connection. The Interconnection System can be internal to the DR.

Inverter: A power electronic device, which converts dc power into ac power.

IPS: Interconnection Protection Settings document, Appendix 3.

Island: A condition in which a portion of the Distribution System is energized by one or more Power Producer generators through their PCC(s) while that portion of the Distribution System is electrically separated from the rest of the Distribution System.

Island, intentional: A planned island.

Island, unintentional: An unplanned island.

Micro-Distributed Resource (micro-DR): Distributed Resource with a nominal operating output voltage of 600 V ac or less.

Micro-DR System: The aggregate micro-DR, inverter(s), Interconnection System(s), control system(s), sensing device(s) or function(s), and protection devices and functions to the Point of DR connection.

Parallel Operation: Refers to the simultaneous energization of a PCC by the Distribution System and the DR System.

Point of Common Coupling (PCC): The point where the Wires Owner's Distribution System is connected to the Power Producer's facilities or conductors.

Point of DR connection: The point where an Interconnection System is electrically connected to the Power Producer's facility. The Point of DR connection can be the same as the PCC.

Power Producer: Any legal entity responsible for generation equipment interconnected to the Distribution System for the purpose of generating electric power.

Secondary Network: A Distribution System configuration used by some utilities in high- density areas. Underground service to customers is at 600 V or less, from a meshed secondary voltage cable network typically supplied from multiple transformers connected to different transmission feeders.

Stabilized: Refers to the Distribution System voltage returning to the normal range of level and frequency for 5 minutes or a time as co-ordinated with the Wires Owner, following a disturbance.

Total Harmonic Distortion (THD): A measure of the total sum of squares of harmonic frequency signals compared to a fundamental frequency signal.

Voltage Follower Mode: An inverter operation mode that follows the waveform of an external source and depends on the external source to initiate and maintain its operation while delivering power to that source.

Voltage Transformer (VT): A device used to transform the potential (voltage) of a circuit to a more useful range for measurement or control. Commonly referred to as Potential Transformer (PT).

Wires Owner: The legal entity responsible for the Distribution System.

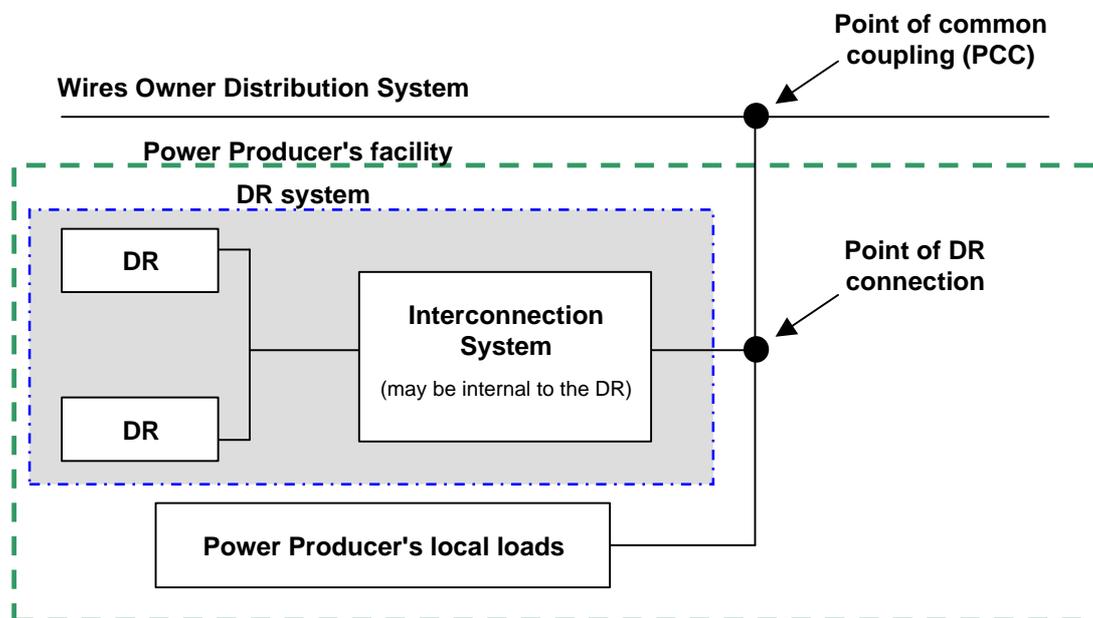


Figure 1: Relationship of DR System and Interconnection Terms

3.2 References

CSA 2002 Canadian Electrical Code Part 1, Nineteenth Edition, C22.1-02, *Safety Standards for Electrical Installations (CE Code)*

CSA C22.2 No. 107.1-01 *General Use Power Supplies (CSA 107.1)*

CSA CAN-3-C235-1983 *95 *Preferred Voltage Levels for AC Systems, 0 to 50,000 Volts, Electric Power Transmission and Distribution*

ANSI C84.1 – 1995 *American National Standard for Power Systems and Equipment – Voltage Ratings (60 Hertz)*

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

IEEE 519 – 1992 *IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems*

IEEE C37.90.1 –2002 *IEEE Standard for Surge Withstand Capability (SWC) Tests for Relays and Relay Systems Associated with Electric Power Apparatus*

IEEE C37.90.2 – 1995 *IEEE Standard for Withstand Capability of Relay Systems to Radiated Electromagnetic Interference from Transceivers*

4.0 GENERAL INTERCONNECTION AND PROTECTION REQUIREMENTS

The Power Producer's DR and Interconnection System must meet all applicable national, provincial and local construction and safety codes. Refer to definitions section for block diagrams showing DR System and Interconnection System connections. Actual micro-DR installations may differ from these samples. Refer to Appendix 1 for an example form of Interconnection Protection Settings (IPS) document listing the specifications of Section 4 that the Interconnection System should meet.

Section 4.1 lists the typical Distribution System operating and power quality conditions within which the DR System operates. It lists representative values of parameters that the Distribution System attempts to maintain and some abnormal conditions that the equipment needs to be designed to withstand.

Section 4.2 lists typical conditions and response to abnormal conditions that the DR System should meet.

Section 4.3 lists typical Interconnection Operational and Protective Function Requirements.

4.1 Distribution System Operating Conditions

It is the Power Producer's responsibility to ensure that the DR System operates correctly in this environment. The Power Producer should ensure that the IPS document is complete.

4.1.1 System Frequency

The Distribution System operates at 60 Hz. Frequency deviations are typically 59.7 Hz to 60.2 Hz for small contingencies that cause modest disturbances, i.e. where the DR System continues energising the Distribution System. For large contingencies, broader frequency variations can occur. These variations can be experienced under severe Distribution System loads, load variations, or when major generation or transmission is lost, or power shedding schemes are employed. The Distribution System frequency and load shedding requirements are governed by the regional Electricity Coordinating Councils amongst interconnected Transmission Systems.

4.1.2 System Voltage

CSA Standard CAN3 C235-83 - *Preferred Voltage Levels for AC Systems 0 to 50,000V* provides general guidance as to appropriate Distribution System steady state service voltage levels. DR Systems must operate satisfactorily within the extreme voltage level variation limits shown in Table 1 and may continue to operate beyond these limits (per 4.2.8) to allow the Wires Owner's automatic voltage regulation equipment time to function. Voltage regulation is a Wires Owner's responsibility and voltage regulation schemes should not be employed by DR Systems except under agreement with the Wires Owner.

Table 1: Recommended Service Voltage Variation Limits

Nominal System Voltages	Recommended Voltage Variation Limits for Circuits Up to 1000 volts, Applicable at Service Entrance			
	Extreme Operating Conditions			
	Normal Operating Conditions			
Single Phase 120/240 240 480 600	106/212 212 424 530	110/220 220 440 550	125/250 250 500 625	127/254 254 508 635
Three Phase 4-Conductor 120/208Y 240/416Y 277/480Y 347/600Y	110/190 220/380 245/424 306/530	112/194 224/388 254/440 318/550	125/216 250/432 288/500 360/625	127/220 254/440 293/508 367/635
Three Phase 3- Conductor 240 480 600	212 424 530	220 440 550	250 500 625	254 508 635

Source: Preferred Voltage Levels for AC Systems, 0 to 50 000V- Canadian Standards Association

4.1.3 Flicker

Distribution Systems generally comply with the flicker limits of IEEE 519-1992.

4.1.4 Voltage Distortion

IEEE-519 sets the quality of power that the utility is to deliver to the customer PCC, and describes the voltage and current waveforms that exist throughout the Distribution System. Transient conditions exceeding the limits may be encountered. Non-interconnected (or Islanded) Distribution Systems and remote sections of rural Distribution Systems may not meet the limits. IEEE 519 Section 11.5 recommends that the voltage distortion limits as a percentage of the

nominal fundamental frequency voltage should not exceed 3% for any individual harmonic, and 5% for the total voltage harmonic distortion THD.

4.1.5 Voltage Unbalance

The voltage unbalance on the Distribution System under normal operating conditions is typically under 3% but may reach 5% due to the unbalanced loading and single-phase voltage regulation. Voltage unbalance is included in the range of Table 1 in section 4.1.2.

Voltage unbalance is calculated using RMS voltage levels measured phase to phase at the service entrance under no load conditions¹:

$$\text{Voltage unbalance (\%)} = 100 \times [(\text{max. deviation from average}) / (\text{average})]$$

4.1.6 Fault Levels

Fault levels on distribution circuits will vary depending on circuit configuration. The Wires Owner will provide information on fault levels at the PCC upon request.

4.1.7 System Grounding

Distribution Systems are typically three-phase 4-wire multi-grounded systems incorporating single-phase distribution taps. They are typically operated as effectively (solidly) grounded.

4.1.8 Fault and Line Clearing

To maintain the reliability of the Distribution System, the Wires Owner may use automatic re-closing. The Power Producer needs to be aware of line re-closing when designing DR System protection schemes to ensure that the DR System ceases to energize the Distribution System prior to automatic re-close of Wires Owner's breakers or line reclosers.

4.1.9 Voltage and Current Surges

The Distribution System may experience voltage and current surges in accordance with the environments described in IEEE/ANSI C62.41 Recommended Practices on Surge Voltage in Low Voltage AC Systems and in IEEE/ANSI C37.90.1 Standard for Relays and Relay Systems Associated with Electric Power Apparatus. The actual environment may vary by location and by other types of equipment connected to the Distribution System, including switched loads, switched power factor correction capacitors, and voltage regulation equipment.

¹ ANSI C84.1-1995, Annex D

4.2 Interconnection System

This section provides the technical requirements to be met by the Interconnection System connecting the micro-DR with the Distribution System. Typical operating conditions, protection functions, and response to abnormal conditions that the Interconnection System should meet are listed.

4.2.1 Safety

Safe work procedures described in the Wires Owner's documents should be followed in providing isolation for work on the Wires Owner's part of the interconnected power system. This may require isolation and grounding of parts of the Power Producer's micro-DR System or facility, and lockout procedures. The Wires Owner may require additional warning tags or labels to be placed.

4.2.2 Point of Common Coupling – Responsibilities and Quantity Measurement

The Point of Common Coupling will be identified in the design and on the Single Line Diagram. The Wires Owner will co-ordinate design, construction, maintenance and operation of the facilities on the Wires Owner side of the PCC. The Power Producer is responsible for the design, construction, maintenance and operation of the facilities on the Power Producer's side of the PCC unless described otherwise in an interconnection agreement between the Power Producer and the Wires Owner.

In regard to protection functions, the aggregate of DR units rated 30 kVA and under may measure voltage level and frequency at the point of DR Connection. Aggregate of DR units larger than 30 kVA may measure voltage amplitude and frequency at the PCC, or at the point of DR connection (as agreed with the Wire Owner) with the voltage trip points set to maintain voltage level at the PCC within limits.

4.2.3 Point of Disconnection - Safety

A disconnecting means to provide a point of disconnection between the DR System and the Distribution System is required. Low voltage disconnecting means must meet the intent of the CE Code. Wire Owners safe work practices may have additional requirements. The purpose of the disconnecting means is to provide safe isolation between the Distribution System and the Interconnection System for safe work purposes².

² Much work has been done, and continues to be performed to develop inverters which ensure the DR will not be able to energize the Distribution System during abnormal system conditions (4.2.8, 4.2.9, 4.2.10). MPC has made recommendations to support changes to the CE Code to revise the requirements for DR System disconnecting means

Switching, lock out and tagging procedures of this disconnecting means typically will be addressed in the interconnection and operating agreements between the wires owner and the power producer.

4.2.4 Phasing

Phasing is not standardised across Distribution Systems. Where necessary, the phase sequence and the direction of rotation must be co-ordinated with the Wires Owner Distribution System.

4.2.5 Interconnection Grounding

DR and Interconnection Systems must be grounded as per manufacturer's recommendations, the CE Code, and take into account the normal practices of the Distribution System.

Interconnection of three phase transformers, and transformer grounding systems on three phase Distribution Systems shall be co-ordinated with the Wires Owners and shall not cause voltage disturbances or disrupt co-ordination of Distribution System ground fault protection.

4.2.6 Interrupting Device Ratings

The design of the DR System must consider the fault current contributions from both the Wires Owner and the DR System itself, to ensure that all circuit fault interrupters are adequately sized. If requested, the Wires Owner will inform the Power Producer of the present and anticipated future fault current contribution from the Wires Owner's Distribution System at the PCC.

4.2.7 Overcurrent Protection

The Power Producer's Interconnection System must detect and promptly cease to energize for overcurrent fault conditions in the DR System.

4.2.8 Over-Voltage and Under-Voltage Protection

Three-phase DR Systems shall cease to energise when any individual phase to neutral voltage on a grounded-wye system or any individual phase to phase voltage on a ungrounded-wye or delta system goes outside the range of Table 2. Single-phase DR Systems shall detect the phase to neutral voltage if connected to neutral. Single-phase equipment connected line to line but not to the neutral conductor shall detect the line to line voltage.

DR Systems rated more than 30 kVA may be required to meet the alternate limits and trip times shown in Table 2.

The DR System shall not attempt to regulate the voltage and shall not adversely affect voltage at the PCC. The Wires Owner will decide if voltage regulation is expected to be a concern and identify possible solutions at time of application.

Table 2: Response to Abnormal Voltage Levels

For DR Systems Rated ≤ 30 kVA		For DR Systems Rated > 30 kVA	
Source CSA C22.2 No. 107.1-01 Table 16			
Voltage Condition	Max. number of cycles to disconnect	Voltage Condition	Max. number of cycles to disconnect
$V < 50\%$	6 cycles	$V < 50\%$	6 cycles
$50\% < V < 88\%$	120 cycles	$50\% \leq V < 88\%$	120 cycles
---	---	$106\% < V < 110\%$	Field adjustable trip may be required*
$110\% < V < 137\%$	120 cycles	$110\% \leq V < 120\%$	120 cycles
		$120\% \leq V < 137\%$	120 cycles (10 cycles may be required)*
$137\% < V$	2 cycles	$137\% \leq V$	2 cycles

**The product standard allows a wider normal voltage range than 4.1.2 to allow line regulation equipment time to function. Field adjustable settings for larger DR Systems may be required to improve protection. Field adjustable settings shall be adjusted by qualified personnel only.*

4.2.9 Over frequency and Under frequency Protection

The DR System shall cease to energize on over and under frequency conditions and at preset delay times as presented in Table3 and shall not reconnect until the Distribution System has stabilized. Additional frequency selective relays to separate the DR System from the Distribution System, in cases of extreme frequency variation, are not normally required. For DR Systems capable of supplying more than 30kVA, at least one adjustable under frequency setting and one over frequency setting with adjustable clearing time is generally advised. Individual DR units rated greater than 30 kVA require adjustable settings. DR units greater than 250 kVA may require a second adjustable under frequency setting. If different than Table 3a, the under frequency settings need to be co-ordinated with the Wires Owner to meet the requirements of the regional Electricity Co-ordinating Council. Island detection schemes should be reviewed if this time is beyond the island detection time limit of 4.2.10.

Table 3a: Frequency Operating Limits for DR ≤ 30 kVA.

Frequency Operating Limits		
		Source CSA C22.2 No. 107.1-01 Table 16
Utility Voltage Condition	Frequency	Maximum number of cycles to disconnect
Rated voltage	$F < \text{rated} - 0.5 \text{ Hz}^*$	6
Rated voltage	$F > \text{rated} + 0.5 \text{ Hz}$	6

*The UL 1741 standard and the new IEEE 1547 use $F < \text{rated} - 0.7$. Update when CSA C22.2 No. 107.1 is changed.

Table 3b: Frequency Operating Limits for DR > 30 kVA.

Frequency Operating Limits		
DR System capacity.	Frequency Range	Number of cycles to disconnect
> 30 kVA	First 59.8 - 57	6 – 18,000
> 250 kVA	Second 59.8 – 56.4*	6 – 18,000
all	$F > 60.5 \text{ Hz}$	6 – 10,800

* Frequencies as low as 55.5 Hz for DR Systems > 250 kVA are required on some systems.

4.2.10 Anti-Islanding

The DR System shall meet the anti-islanding requirements of CSA C22.2 No. 107.1 and cease to energize the Distribution System within a time no greater than two seconds after the formation of an unintentional island.

Intentional island conditions are not covered in this document.

4.2.11 Power Factor

The DR System is not required to be capable of adjusting the power factor but shall operate in the preferred range of ± 0.85 . If the DR System disturbs the Distribution System voltage levels at the PCC then the power producer may be required to operate the DR System within a smaller range or take other compensatory measures. Field settable fixed and dynamic power factor correction techniques may be used if consultation with the Wires Owner reveals no adverse affect on the Distribution System

4.2.12 Flicker

The DR System shall not cause objectionable flicker on the Distribution System. It is recognised that flicker is a site dependent condition. Refer to IEEE 519-1992 and the Wires Owner for specific site requirements.

4.2.13 Harmonics

DR Systems are expected to comply with IEEE-519 current distortion limits, as listed in Table 4. For inverters only capable of operating in voltage follower mode, voltage harmonic distortion limits are not specified, but may be addressed by the Wires Owner. Inverters certified to CSA 107.1 are considered to meet these requirements. The CSA standard excludes current harmonics due to voltage distortions in the Wires Owner’s Distribution System. Total current harmonic distortion shall not exceed 5% of rated current.

Table 4: Limit of Current Harmonic Distortion

Limits of Current Harmonic Distortion* *Source CSA C22.2 No. 107.1-01 Table 15		
Harmonic Numbers	Maximum distortion	
	Even Harmonics	Odd harmonics
2 nd through 9 th	1.0%	4.0%
10 th through 15 th	0.5%	2.0%
16 th through 21 st	0.4%	1.5%
22 nd through 33 rd	0.2%	0.6%
Above 33 rd	0.1%	0.33%

4.2.14 Voltage Unbalance

When single phase DR units are connected in multiple units, if three phase service is available, then approximately equal amounts of generation capacity should be applied to each phase of a three-phase circuit.

4.2.15 DC Injection

The DR System shall not inject a dc current greater than 0.5% of the unit rated output current after a period of six cycles following energizing of the Distribution System.

4.2.16 Energizing Wires Owner Distribution System

The DR System shall not energize the Distribution System until the Distribution System is Stabilized.

4.2.17 Protection from Electromagnetic Interference

The influence of EMI should not interfere with operation of the DR System. Capability of meeting the intent of *IEEE C37.90.2 Standard for Withstand Capability of Relay Systems to Radiated Electromagnetic Interference from Transceivers* may be considered adequate.

4.2.18 Surge Withstand Performance

The influence of voltage and current surges should not interfere with operation of the DR System.

4.2.19 Synchronization

DR Systems that can generate an ac voltage waveform independent of the Distribution System shall be connected in parallel with the Wires Owner Distribution System only in combination with synchronizing capabilities. The method of synchronization shall be specified in the IPS. The DR System shall energize the Distribution System while meeting the flicker requirements of 4.1.3 and without causing voltage variation at the PCC of greater than 5%. The DR System may synchronise when the Distribution System is Stabilized.

4.2.20 Data Telemetry

DR units, or aggregated DR units at a single PCC, rated at greater than 250 kVA shall have provision for monitoring connection status, real power output, reactive power output, and voltage either at the point of connection or aggregate connection. The monitoring equipment shall either be installed, or adequate design work done to allow future installation of such equipment if not required at time of interconnection. When implementation of data telemetry is required, the Wires Owner and Power Producer will mutually agree upon communication media options. Recommended telemetry communication media are non-dedicated lines for the class of equipment covered under this guideline. Control or dispatch of the DR System is not normally possible nor required by the Wires Owner.

4.3 Typical Interconnection Operational and Protective Function Requirements

An Interconnection Protection Settings (IPS) document shall be provided by the Power Producer to the Wires Owner to determine the acceptability of the Interconnection System and settings. See Appendix 3. The Interconnection System shall meet the applicable protective functions in Table 5.

Table 5: Interconnection Protection Function Requirements^{1,2,3}

Function	1 Phase	3 Phase		
		≤ 30 kVA	30 kVA – 250 kVA	≥ 250 kVA
AC Disconnect Means	Y	Y	Y	Y
Anti-Islanding	Y	Y	Y	Y
25 Automatic Synchronizing ⁴	Y	Y	Y	Y
27 Under-Voltage Trip	Y	Y(3)	A(3)	A(3)
59 Over-Voltage Trip	Y	Y(3)	A(3)	A(3)
50 Instantaneous Overcurrent ⁷	Y	Y(3)	Y(3)	Y(3)
51 Timed Overcurrent ⁷	Y	Y(3)	Y(3)	Y(3)
81/U Under-Frequency Trip	Y	Y	A	A
81/O Over-Frequency Trip	Y	Y	Y	Y
Secondary Injection Capability				Y

Notes:

1. Interconnection of 1 and 3 phase generation units connected at 600 volts or less in accordance with Canadian Electrical Code
2. Y - required, A - adjustable set points may be required as per 4.2.8 and 4.2.9.
3. Number of phases monitored shown in parentheses, e.g. (3)
4. Inverters with standalone capability.
5. 50/51 functions may be met by fuses or breaker

4.3.1 Mitigation of Protection System Failure

Any element of the Interconnection System external to the certified DR unit should be installed in a fail safe manner with self checking features or redundant protection functions.

4.4 Interconnection Approval Minimum Requirements

The Power Producer shall provide to the Wires Owner documentation listed in section 7 for review of potential impacts on the Distribution System.

5.0 REVENUE METERING

Metering equipment, where required for commercial purposes, shall be revenue class and shall comply with Measurement Canada requirements and local Wires Owner's standard requirements. The metering arrangements and agreements will be negotiated between the Power Producer and the Wires Owner or Energy Retailer.

6.0 INSPECTION, TESTING AND COMMISSIONING

6.1 General

In addition to the Power Producer's normal inspection procedures, the Wires Owner may reserve the right to witness any part of work that concerns the DR System; to inspect materials, documents and installation procedures, to witness tests and to evaluate results of non-destructive examinations. The Power Producer shall notify the Wires Owner in writing at least 2 weeks before the initial energizing and start-up testing of the DR System and the Wires Owner may witness the field testing of any equipment and protective systems associated with the Interconnection System. Wherever practical, inspection timing and scheduling shall be mutually agreed by the Power Producer and the Wires Owner.

Step by step energizing and commissioning procedures shall be provided to the Wires Owner prior to DR System commissioning. The Power Producer shall make available to the Wires Owner a complete set of manuals, for use by the Wires Owner during inspection, testing, and commissioning.

6.2 Type Testing

All inverters shall be certified to CSA 107.1 or be demonstrated to meet the anti-islanding test in CSA 107.1 as part of another product certification standard. The DR System documentation must include a type test procedure as part of the documentation.

6.3 Commissioning and Verification Testing

Prior to completion of commissioning of a DR System, or when DR System hardware or software is changed (see 6.3.3), a verification test must be performed. The Wires owner reserves the right to witness verification testing or require written certification that the testing was performed.

All verification tests relating to the Interconnection System prescribed by the manufacturer or developed by the Power Producer that are agreed to by the Wires Owner shall be performed prior to interconnection. The Power Producer shall maintain verification test reports for inspection by the Wires Owner.

Any system that depends upon a battery for trip power shall be verified to be of fail safe design by disconnecting the battery and verifying that the system ceases to energize the Distribution System.

6.3.1 Protective Function Testing

- (i) If microprocessor-controlled protective functions are used, and production line testing has been done to verify conformance with 4.2.8, 4.2.9, and 4.2.10, then a repeat of the production line testing (subject to item (ii) below) in the field is not required. Recommended manufacturer commissioning testing is required.
- (ii) The anti-islanding function shall be checked by operating a disconnecting means to verify that the DR System ceases to energize the Distribution System and does not energize the Distribution System for the required time delay after the disconnecting means is closed.
- (iii) A reverse power to utility or minimum forward power function, if used to meet the interconnection requirements, must be tested using secondary injection techniques. Power should be sensed on all phases to which the power producer's DR System is connected. Alternatively, this function can be tested by means of a local load trip test or by adjusting the DR System output and local loads to verify that the applicable non-export criterion (i.e., reverse power or minimum power) is met.
- (iv) If batteries are used, verify that the protection settings are stored in non-volatile memory. Disconnection or removal of batteries for a minimum of 10 minutes without change of the protection settings is an acceptable method of demonstrating non-volatile memory.
- (v) Testing of the Interconnection System, where required, shall include procedures to functionally test all protective elements of the DR System up to and including cease to energize the Distribution System at the point of DR System connection. Testing will verify all adjustable protective set points, if any, and relay/breaker trip timing, if any. Testing should occur after VTs (PTs), CTs and other field equipment are calibrated and verified per 6.3.2. Power Producer's DR System rated 250 kVA or larger should include set point adjustment, secondary injection, or other means acceptable to the Wires Owner.

6.3.2 Verification of Final Protection Settings

If protective function settings have been adjusted as part of the commissioning process, then, at the completion of such testing, the Power Producer shall confirm all protective function settings are set to the Wires Owner's accepted settings and are protected from changes by unauthorized personnel (password protection is recognized as an efficient method).

Interconnection protective devices or functions that have not previously been tested as part of the Interconnection System with their associated instrument transformers or that are wired in the field shall be given an in-service test during commissioning. This test shall verify proper wiring, polarity, sensing signals, CT/VT (PT) ratios, and proper operation of the measuring circuits.

6.3.3 Hardware or Software Changes

Whenever DR System hardware or software is changed, the Power Producer must obtain test result documentation from the manufacturer showing the changes and new certification information (where the unit was previously certified). A qualified installer must install the new hardware or software and perform verification testing in accordance with the equipment manufacturer's published test procedure. Qualified individuals include professional engineers, factory trained and certified technicians, and licensed electricians with experience in testing such equipment. The updated certification or test result documentation obtained from the manufacturer must ensure that the following criteria have been verified:

1. Over-voltage and under-voltage
2. Over-frequency and under-frequency
3. Anti-islanding function
4. Inability to energize dead line
5. Time delay restart after Wires Owner outage
6. Overcurrent, (if applicable)
7. Synchronizing controls (if applicable)
8. Current Harmonics
9. DC Injection

Verification of final protection settings shall be performed as per 6.3.2.

6.4 Auxiliary Equipment

The Wires Owner reserves the right to witness the testing of installed auxiliary equipment, for example switchgear, capacitor banks, etc. The Power Producer shall notify the Wires Owner at least two weeks prior to any testing.

7.0 DATA REQUIREMENTS

Table 6 lists the information required by the Wires Owner for the acceptance of the project. The Proposal Stage should be completed prior to detailed DR System design to determine if there are additional requirements, for example due to high penetration levels of DR on a Distribution System. The Acceptance Stage is generally when the application for interconnection is approved. The minimum time requirement for review of information at this stage will generally be of the order of 10 working days. The Commissioning Stage is the final field verification of settings when the DR System first energizes the Distribution System.

Table 6: Drawings and Data Requirements

Drawing/Data	Proposal Stage	Acceptance Stage	Commission Stage
Manufacturer’s Equipment Data Sheet, Interconnection Protection Settings (IPS) document in Appendix 3		X	X
Single Line Diagram indicating proposed protection settings.	X	X	X
Description of Protection Scheme, if any, in addition to DR integrated protection.		X	X
DR nameplate information		X	X
Protective function settings		X	X
Commissioning Report c/w Protection Settings, where field adjustable per 6.3.2			X
Plot plan with location of disconnecting means and PCC.	X	X	X

8.0 MAINTENANCE & OPERATION

The Power Producer has full responsibility for routine maintenance of the Power Producer’s DR System and keeping records of such maintenance to the recommendations of the equipment manufacturer and accepted industry standards, in particular CE Code Part 1, paragraph 2-300.

Interconnection System protection functions operation shall be verified according to the manufacturer’s recommended schedule, or at least annually if there is no manufacturer recommendation. Operating the disconnecting means and verifying that the DR System automatically ceases to energize the Distribution System and does not resume energizing until the Distribution System is Stabilized after the disconnecting means is closed is an acceptable verification method.

Failure to maintain CE Code and industry acceptable facilities and maintenance standards can result in disconnection of the power producer facility.

**ANNEX 1
INTERCONNECTION PROTECTION SETTINGS (IPS) DOCUMENT**

Interconnection Protection Settings Document

Interconnection Protective Function Equipment Nameplate Information - Type of Equipment (Inverter, Circuit breaker, Other – specify _____)
 Use a separate form for each piece of equipment providing protective functions

Manufacturer		Brand		Model	
Capacity Rating	KVA	Certification Std.		Date of Manufacture	
Nominal ac Voltage	V	Frequency	Hz	Number of Phase	<ul style="list-style-type: none"> • Single • Three
ac Voltage Range		Output Freq. Range		Max. % Voltage Unbalance (if applicable)	

Protection Characteristics: Specify test method
 Verify that the equipment detects and ceases to energize for the following protection functions: (* for units > 30kW, ** for units > 250kVA, *** time to trip should be verified for field adjustable devices other than inverter based.)

Over-Voltage Trip Function

Voltage to Trip						Duration to trip (cycles)							
Guideline Limit	Adjustable Range	As left	Tested**			Guideline Limit	Adjustable Range	As left	Tested***				
			A	B	C				A	B	C		
106%<V≤110%							*						
110%<V≤120%						120							
120%<V≤137%						120/10*							
137% < V						2							

Under-Voltage Trip Function

Voltage to Trip						Duration to trip (cycles)							
Guideline Limit	Adjustable Range	As left	Tested**			Guideline Limit	Adjustable Range	As left	Tested***				
			A	B	C				A	B	C		
V<50%						2							
50%<V≤88%						120							

Under-Frequency Trip Function

Frequency to Trip						Duration to trip (cycles)							
Guideline Limit	Adjustable Range	As left	Tested**			Guideline Limit	Adjustable Range	As left	Tested***				
			A	B	C				A	B	C		
<59.5Hz	*					6	*						
**							**						

Over-Frequency Trip Function					
Frequency to Trip			Duration to trip (Cycles)		
Guideline Limit	Adjustable Range	As left	Tested**		
			A	B	C
≥60.5 Hz					

Over-Current Trip Function Rating and Method (breaker, fuse, etc.)						
Current to Trip			Duration to trip (s)			
	Method	Rating	Adjustable Range (if Applicable)	Method	Time	Adjustable Range (if Applicable)
Instantaneous						

Anti-Islanding Function		
Test	Requirement	Result of test
Loss of utility voltage	Immediate trip	
Unit restart delay after Utility voltage returns	≤5 minutes	
Dead Bus test	No start	• YES • NO

Synchronization Limits for Stand-Alone Inverters				
	Guideline Limit	Adjustable range	As Left	Document Synchronizing Method:
Frequency Difference				
Voltage Difference				
Phase Angle Difference				

Equipment & Test Certification	
Date of test: _____ Wire Owner Witness (Y/N) ____ Signature: _____	
Authorized Personnel (if setpoints adjusted):	
Additional Notes/ Comments:	
Received by:	Provided by:
_____	_____
WIRES OWNER	POWER PRODUCER
_____	_____
TITLE	TITLE
_____	_____
DATE	DATE

INFORMATIVE ANNEX A

SINGLE LINE DIAGRAMS FOR TYPICAL MICRO-DR TECHNOLOGIES

FIGURE A-1: GRID-DEPENDENT MICRO-DR USING SOLAR PV, FUEL CELL, MICRO-HYDRO, OR DC-GENERATING WIND SYSTEMS

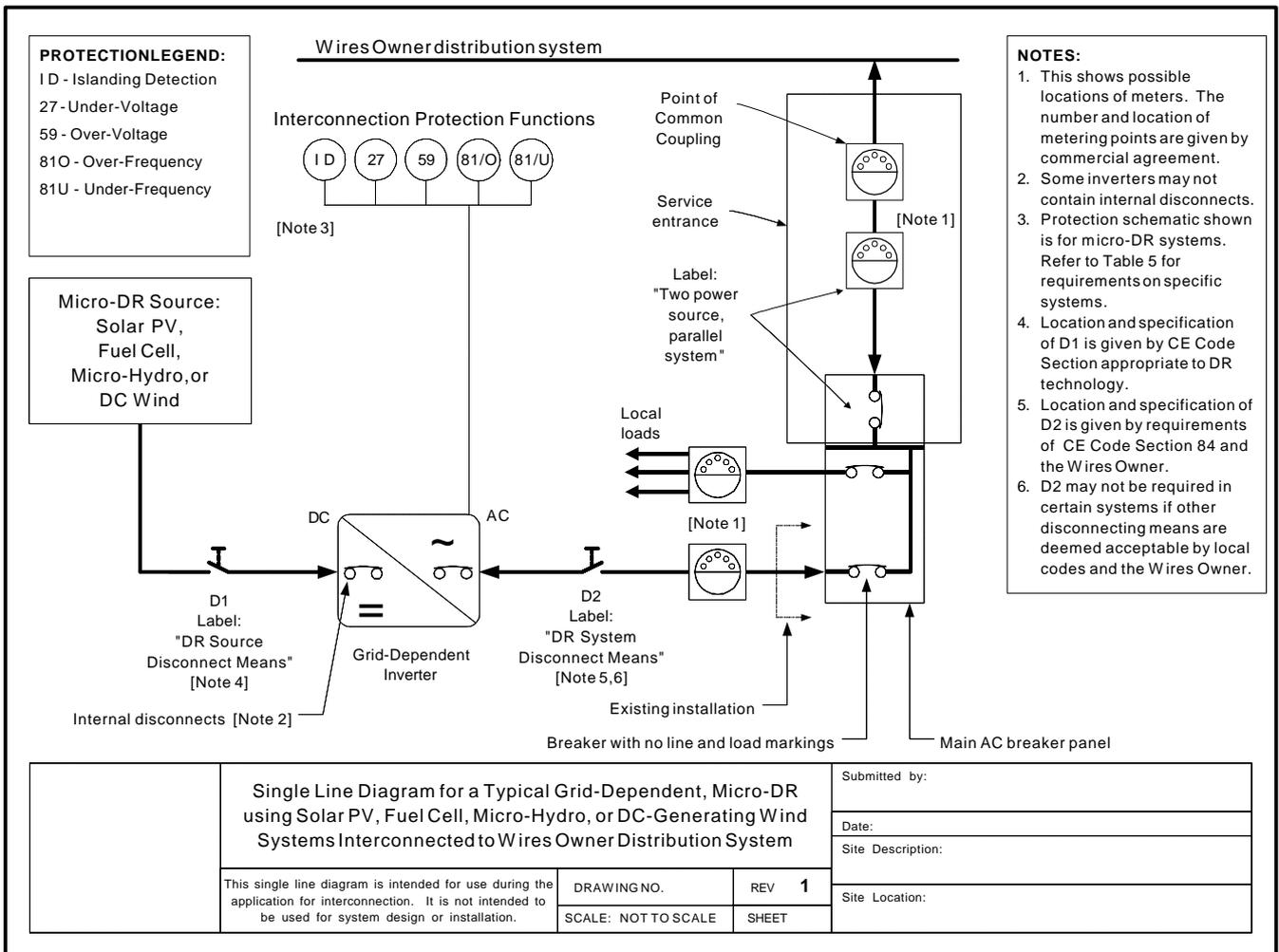


FIGURE A-3: MICRO-DR USING AC-GENERATING WIND SYSTEMS

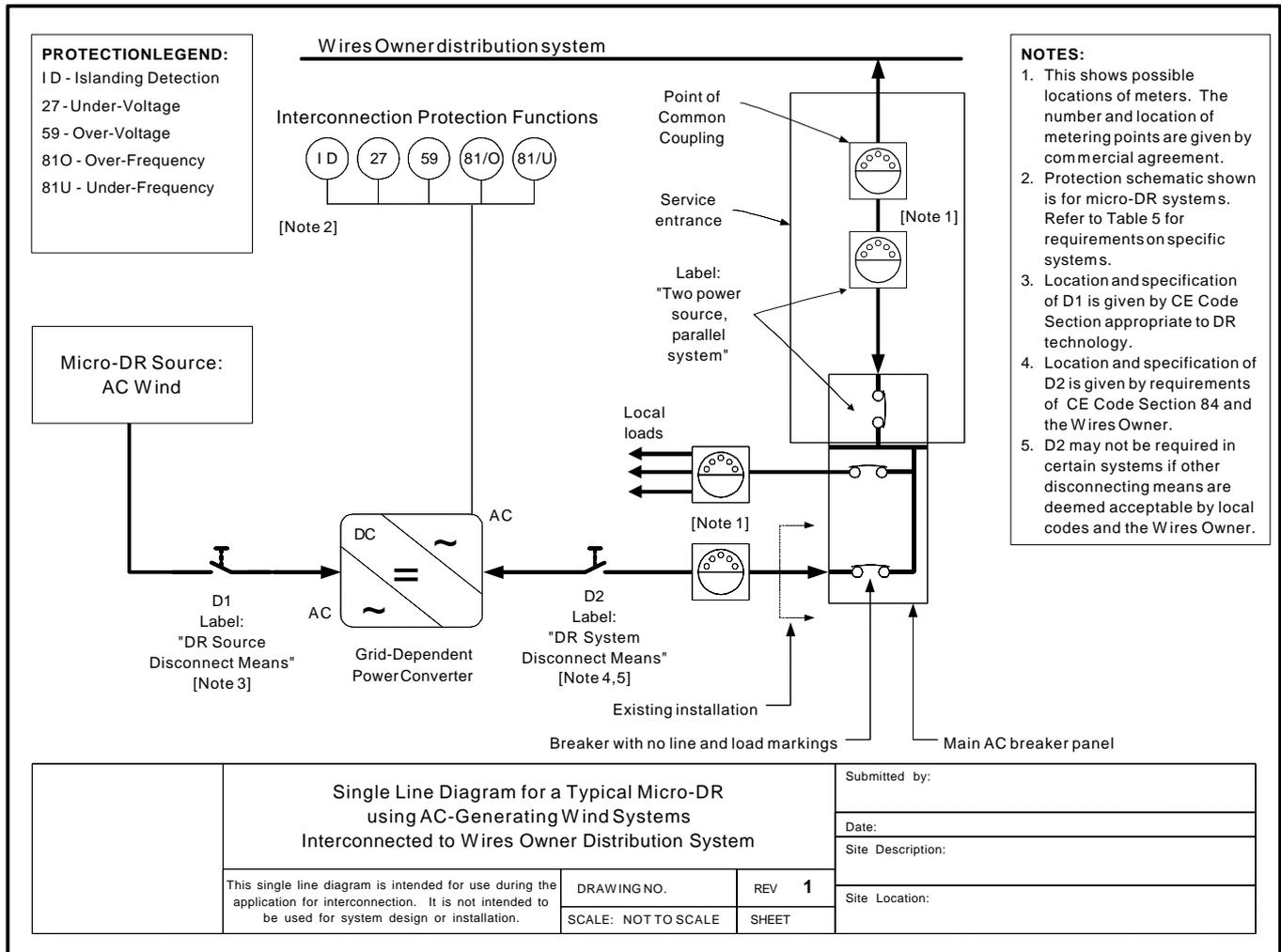
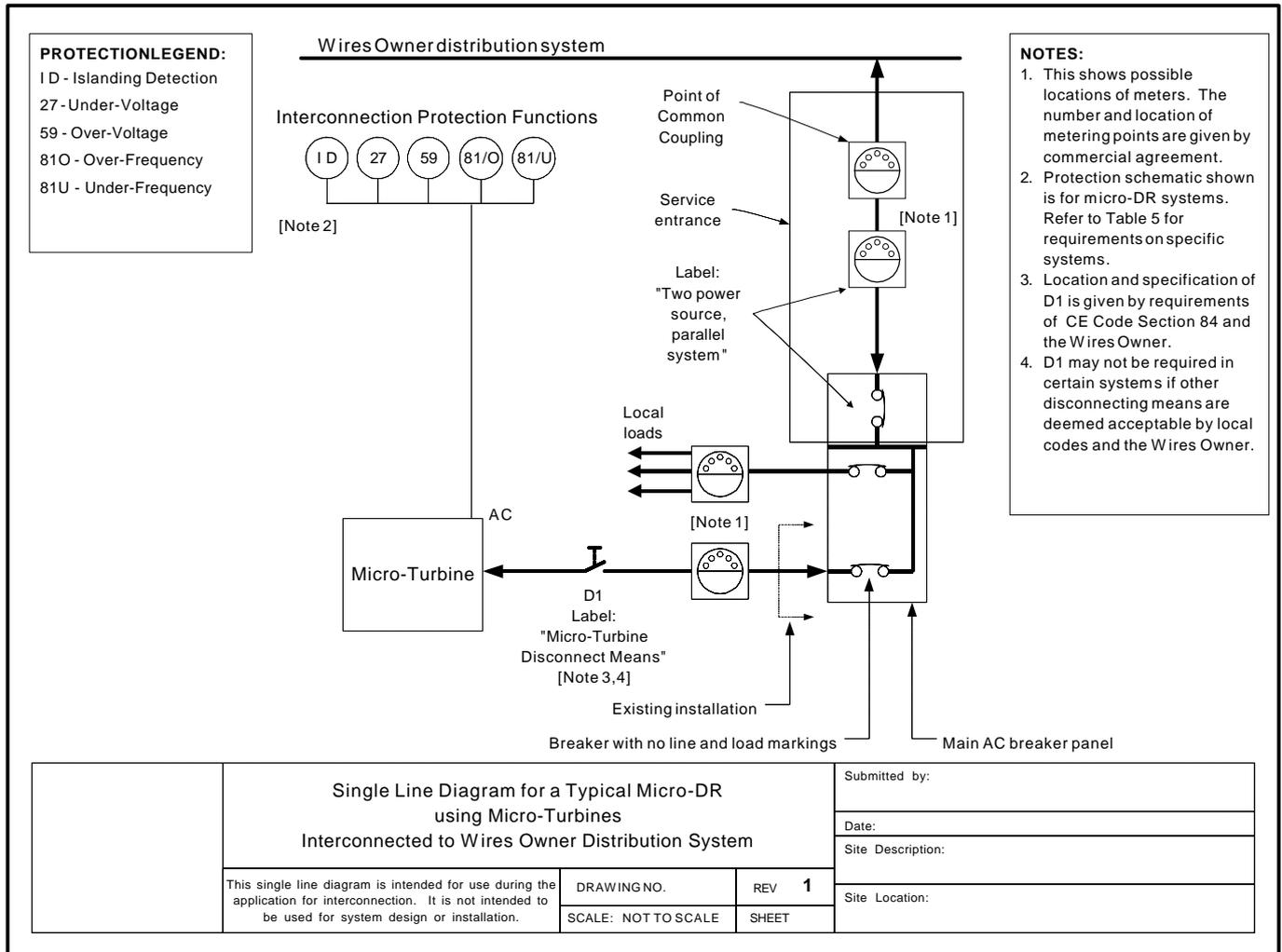


FIGURE A-4: MICRO-DR USING MICRO-TURBINES



INFORMATIVE ANNEX B

INVERTER CLASSIFICATIONS AND OPERATING MODES

This informative annex is intended to provide a basic awareness of the types of inverters available and their operation.

B.1 Classification based on the dc link

Voltage source inverter: An inverter in which the dc link has a constant voltage, usually by way of a bank of capacitors, battery cells, or other electrical storage device.

Current source inverter: An inverter in which the dc link has a constant current, usually by way of an inductor.

B.2 Classification based on method of commutation

Self-commutated inverter: An inverter in which its semiconductor devices such as transistors, IGBTs, MOSFETs, GTOs and thyristors can be turned off by their own control circuits or auxiliary circuits. Most grid-connected inverters are self-commutated. Also known as a forced-commutated inverter.

Line-commutated inverter: An inverter in which its semiconductor devices, such as thyristors, are turned off with the help of an external source. Most line-commutated inverters are current controlled.

Load-commutated inverter: An inverter in which its semiconductor devices, such as thyristors, are turned off with the help of a load such as a synchronous motor.

B.3 Classification based on the output control

Voltage controlled inverter: An inverter that directly controls its voltage output.

Current controlled inverter: An inverter that directly controls its current output: waveform, magnitude and phase angle. Most grid-connected inverters and small inverters are of this type.

B.4 Classification based on the output waveforms

Sinusoidal wave inverter: An inverter that has a sinusoidal- output waveform.

Square wave inverter: An inverter that has a periodic square wave output, 180 degrees positive followed by 180 degrees negative.

Modified sine wave inverter: An inverter that has a periodic quasi-square wave output, usually 120 degrees positive, 60 degrees zero, 120 degrees negative, 60 degrees zero.

Voltage-following inverter: An inverter that operates in voltage-following mode.

B.5 Classification based on relationship to utility interconnection

The following modes can describe inverter operation:

- a) **Stand-alone mode:** in which an inverter operates in isolation from a Wires Owner's distribution facility, and generates its own voltage, phase, and frequency conditions.
- b) **Grid-parallel mode:** in which an inverter operates in parallel with a Wires Owner's distribution facility and contains provision for synchronising its voltage, phase, and frequency to that facility.
- c) **Grid-dependent mode:** in which an inverter operating in grid-parallel mode depends on a Wires Owner's distribution facility to initiate and maintain its operation.

Stand-alone inverter: An inverter that operates only in stand-alone mode and thus contains no facility to synchronise its output with a Wires Owner's distribution facility (can also be termed a grid-isolated inverter).

Grid-connected inverter: An inverter that is able to operate in grid-parallel mode. Also known as a grid-intertie or a grid-tied inverter.

Grid-dependent inverter: A type of grid-connected inverter that operates only in grid-dependent mode.

Grid-interactive inverter: A type of grid-connected inverter that is able to operate in both stand-alone and grid-parallel modes according to the availability of the Wires Owner distribution facility. It can be considered as a UPS that is also able to operate in grid-parallel mode. Note that this type of inverter initiates grid-parallel operation.

B.6 Classification based on the number of output phases

Single-phase inverter: An inverter that generates a single-phase electrical output.

Three-phase inverter: An inverter that generates a three phase electrical output. Also known as a poly-phase inverter.