TECHNICAL REQUIREMENTS

for Interconnection and Interoperability of Distributed Energy Resources on EPCOR's Electric Distribution System

EDTI INTERCONNECTION GUIDE

Release date November 28, 2022 - Effective March 31, 2023

AUTHENTICATIONS & PERMIT TO PRACTICE

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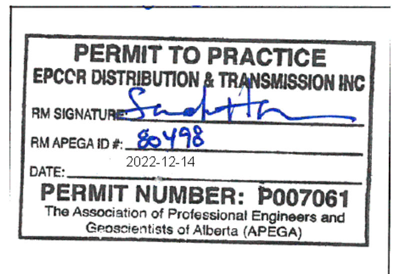
Entire Document	

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1.0

Introduction

1.1 INTRODUCTION

Distributed Energy Resource (DER) is a source of electric power that is not directly connected to a bulk power transmission system. DERs include distributed generation and energy storage technologies.[1]

The Technical Requirements for Interconnection and Interoperability of Distributed Energy Resources on EPCOR's Electric Distribution System henceforth refered to as the Technical Requirements establishes criteria and requirements for the interconnection of DERs within the electric distribution system of EPCOR Distribution and Transmission Inc. (EDTI). Specifically, the Technical Requirements defines the technical requirements for connecting DERs that are not exclusively owned by EDTI, but are connected to EDTI's distribution system, with an operating voltage of 25,000 V (25 kV) or lower. Requirements relevant to the safety, performance, operation, testing and maintenance of the interconnection are provided.

The requirements established in this document cover a broad spectrum of interests. The addition of DERs to the distribution system may change the system and its response. Attaining a technically sound and safe interconnection between DERs and the distribution system mandates diligence on the part of everyone involved in the interconnection. The Technical Requirement needs to be cooperatively understood and met by everyone involved in the interconnection, including designers, manufacturers, users, owners and operators of both DERs and distribution systems.

The Technical Requirements have been developed with reference to national and international standards such as Canadian Standards Association (CSA) C22.3 No. 9:20, Interconnection of Distributed Energy Resources and Electricity Supply Systems, and the Institute of Electrical and Electronic Engineers (IEEE) standard 1547-2018, IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces.

This document does not constitute a design handbook. Power producers who are considering the development of a DER facility intended for connection to EDTI's distribution system should engage the services of a professional engineer or a registered consulting firm qualified to provide design and consulting services for electrical interconnection facilities.

[1] CSA C22.3 No.9:20

2.0

Limitation of Liability and Disclaimer

2.1 LIMITATION OF LIABILITY AND DISCLAIMER

The requirements specified in this document are minimum requirements for the interconnection of DERs to EDTI's distribution system. Additional requirements may have to be met by both the DER producers and EDTI to ensure the final interconnection design meets all local, national and international standards and codes, and is safe for the application intended.

The Technical Requirement does not address any liability provisions agreed to elsewhere by both parties in a commercial agreement or tariff terms and conditions.

The requirements outlined in the Technical Requirement are based on a number of assumptions, only some of which have been identified. Changing system conditions, standards and equipment may make those assumptions invalid. Use of the Technical Requirement and the information it contains is at the user's sole risk. EDTI, nor any person employed on its behalf, makes no warranties or representations of any kind with respect to the TR, including, without limitation, its quality, accuracy, completeness or fitness for any particular purpose, and EDTI will not be liable for any loss or damage arising from the use of the TR, any conclusions a user derives from the information in the Technical Requirement or any reliance by the user on the information it contains. EDTI reserves the right to amend any of the requirements at any time. Any person wishing to make a decision based on the content of the Technical Requirement should consult with EDTI prior to making any such decision.

3.0

Acronyms and Definitions

For the purposes of this document, the following terms and definitions apply

3.1 ACRONYMS

ACPF – Adjustable constant power factor

ACQ – Adjustable constant reactive power

AESO – Alberta Electric System Operator

AIES – Alberta Interconnected Electric System

AC – Alternating Current

CEC – Canadian Electrical Code

CHP – Combined-heat and power

COG – Coefficient of grounding

CSA – Canadian Standards Association

DC – Direct Current

DERMS – Distributed Energy Resource Management Systems

DESS – Distributed energy storage systems

DTT – Direct Transfer Trip

EDTI – EPCOR Distribution and Transmission Inc.

EEDS – EDTI's Electric Distribution System

EMI – Electromagnetic interference

ES – Energy Storage

IEC – International Electrotechnical Commission

IEEE – Institute of Electrical and Electronics Engineers

NDZ – Non-Detection Zones

NP – Network Protector

NRTL – Nationally Recognized Testing Laboratory (NRTL)

OLTC – On Load Tap Changer

PV – Photovoltaics

Q(P) – Reactive power as function of active power

Q(V) – Reactive power as function of voltage

RMS – Root-Mean-Square

THD – Total Harmonic Distortion

UL – Underwriters Laboratories

3.2 DEFINITIONS

Available active power – Active power that a DER can deliver to the EEDS subject to the availability of the DER's primary source of energy.

Bulk power system (BPS) – Any electric generation resources, transmission lines, interconnections with neighbouring systems, and associated equipment.

Cease to energize – Cessation of active power delivery under steady-state and transient conditions, and limitation of reactive power exchange.

Clearing time – The time between the start of an abnormal condition and the DER ceasing to energize the EEDS. It is the sum of the detection time, any adjustable time delay, the operating time plus arcing time for any interposing devices (if used), and the operating time plus arcing time for the interrupting device (used to interconnect the DER with the EEDS).

Continuous operation – Exchange of current between the DER and the EEDS within prescribed behaviour while connected to the EEDS and while the applicable voltage and the system frequency is within specified parameters.

Distributed energy resource (DER) – A source of electric power not directly connected to a bulk power system. DER includes both generators and energy storage technologies capable of exporting active power to the EEDS.

Distributed energy resource operator (DER operator) – The entity responsible for operating and maintaining the distributed energy resource.

Distributed energy resource system – the DERs, interconnection systems, control systems, sensing devices or functions, and protection devices or functions up to the point of the DER connection.

DER Interconnection – The result of the process of adding DER to the EEDS, whether directly or via intermediate site facilities.

DER Interconnection equipment – Individual or multiple devices used in an interconnection system.

Disconnecting means – a device, group of devices, or other means whereby the conductors of a circuit can be disconnected from their source of supply.

Disturbance period – The range of time during which the applicable voltage or the system frequency is outside the continuous operation region.

Emergency systems – DER systems designated by authority having jurisdiction as emergency, legally required, or critical operations power systems providing backup power to hospitals, fire stations or other emergency facilities as defined by applicable industry code.

Energize – Active power outflow of the DER to the EEDS under any conditions (e.g., steady state and transient).

EPS – Electric power system.

Enter service – Begin operation of the DER with an energized circuit on the EEDS.

Flicker – The subjective impression of fluctuating luminance caused by voltage fluctuations.

Interface – An electrical or logical connection from one entity to another that supports one or more energy or data flows implemented with one or more power or data links.

Interoperability – The capability of two or more networks, systems, devices, applications, or components to externally exchange and readily use information securely and effectively.

Inverter – A machine, device, or system that changes direct-current power to alternating-current power.

Island –

a) The portion of the distribution system that is energized by one or more DERs through their PCC(s) while that portion is separated electrically from the rest of the distribution system; or

b) The condition in which a portion of the distribution system is energized by one or more DERs through their PCC(s) while that portion is separated electrically from the rest of the distribution system.

Intentional — a planned island.
Unintentional — an unplanned island.

When an island exists, the DER energizing the island may be said to be "islanding".

Load – Devices and processes in a site that use electrical energy for utilization, exclusive of devices or processes that store energy but can return some or all of the energy to the site or the EEDS in the future.

Local DER communication interface – A local interface capable of communicating to support the information exchange requirements specified in this standard for all applicable functions that are supported in the DER.

Local electric power system (Local EPS) – An EPS contained entirely within a single premises or group of premises.

Mandatory operation – Required continuance of active current and reactive current exchange of DER with the EEDS as prescribed, notwithstanding disturbances of the EEDS voltage or frequency having magnitude and duration severity within defined limits.

Mandatory operation region – The performance operating region corresponding to mandatory operation.

Medium voltage – A class of nominal system voltages equal to or greater than 1 kV and less than or equal to 35 kV.

Microgrid – A local energy grid with control capability on a customer site, which means it can disconnect from the EEDS and operate autonomously.

Momentary cessation – Temporarily cease to energize the EEDS, while connected to the EEDS, in response to a disturbance of the applicable voltages or the system frequency, with the capability of immediate Restore Output of operation when the applicable voltages and the system frequency return to within defined ranges.

Momentary cessation operation region – The performance operating region corresponding to momentary cessation.

Manufacturer stated measurement accuracy – Accuracy declared by the manufacturer, at which a DER measures the applicable voltage, current, power, frequency, or time.

Nameplate ratings – Nominal voltage (V), current (A), maximum active power (kW), apparent power (kVA), and reactive power (kvar) at which a DER is capable of sustained operation. For Local EPS with multiple DER units, the aggregate DER nameplate rating is equal to the sum of all DERs, not including aggregate capacity limiting mechanisms such as coincidence factors, plant controller limits, etc., that may be applicable for specific cases.

Normal operating performance category – The grouping for a set of requirements that specify technical capabilities and settings for DERs under normal operating conditions, i.e., inside the continuous operation region.

Open loop response time – The duration from a step change in control signal input (reference value or system quantity) until the output changes by 90% of its final change, before any overshoot.

Operating mode – Mode of DER operation that determines the performance during normal or abnormal conditions.

Performance operating region – A region bounded by point pairs consisting of magnitude (voltage or frequency) and cumulative time duration which are used to define the operational performance requirements of the DER.

Permissive operation – Operating mode where the DER performs ride-through either in mandatory operation or in momentary cessation, in response to a disturbance of the applicable voltages or the system frequency.

Permissive operation region – The performance operating region corresponding to permissive operation.

Permit service – A setting that indicates whether a DER is allowed to enter or remain in service.

Per unit (p.u.)/percent of (%) – Quantity expressed as a fraction of a defined base unit quantity.

- For active power (active current), the base quantity is the rated active power (rated active current).
- For apparent power (current), the base quantity is the rated apparent power (rated current).
- For system frequency, the base quantity is the nominal frequency (i.e., 60.0 Hz in North America).

Quantities expressed in per unit can be converted to quantities expressed in percent of a base quantity by multiplication with 100.

Point of common coupling (PCC) – The point on the EEDS that is electrically closest to the power producer’s facility, where other customers are connected or can be connected.

Point of distributed energy resources connection (point of DER connection – PoC) – The point where a DER unit is electrically connected in a site and meets the requirements of this standard exclusive of any load present in the respective part of the site.

Post-disturbance period – The period starting upon the return of all applicable voltages or the system frequency to the respective ranges of the mandatory operation region or continuous operation region.

Power producer – A legal entity responsible for a DER system that is interconnected to the EEDS for the purpose of generating electric power.

Pre-disturbance period – The time immediately before a disturbance period.

Reference point of applicability (RPA) – The location where the interconnection and interoperability performance requirements specified in this standard apply.

Regional reliability coordinator – The functional entity that maintains the real-time operating reliability of the bulk electric power within a reliability coordinator's area.

Restore output – Return operation of the DER to the state prior to the abnormal excursion of voltage or frequency that resulted in a ride-through operation of the DER.

Return to service – Enter service following recovery from a trip.

Ride-through – Ability to withstand voltage or frequency disturbances inside defined limits and to continue operating as specified.

Standby DER – A DER that is only being operated in parallel to the EEDS:

- For testing purposes only and tests are not performed more frequently than 30 times per year; or
- During load transfer in a period of less than 100 ms to or from the EEDS.

Step response – The output as a function of time, *t*, when the input is a step.

Supplemental DER device – Any equipment (capacitor banks, protection devices, plant controllers, etc.) that are used to obtain compliance with some or all of the interconnection requirements of this standard.

Total rated-current distortion (TRD) – The total root-sum-square of the current distortion components (including harmonics and inter-harmonics) created by the DER unit expressed as a percentage of the DER rated current capacity (Irated).

Trip – Inhibition of immediate return to service, which may involve disconnection.

Type test – A test of one or more devices manufactured to a certain design to demonstrate, or provide information that can be used to verify, that the design meets the requirements specified in this standard.

Zero-sequence continuity – Circuit topology providing continuity between two defined points in the zero-sequence network representation.

4.0

Normal Operating Conditions of EDTI's Electric Distribution System

EDTI's Electric Distribution System (EEDS) consists of circuits supplied by three primary voltage levels: 4.16 kV, 13.86 kV and 24.94 kV. Within EDTI, these voltage levels are also commonly referred to as 5 kV, 15 kV, and 25 kV, respectively. EDTI is mandated to maintain the EEDS within the limits specified by Canadian Standard Association (CSA) and Alberta Electric System Operator (AESO)'s standards/rules.

4.1 SYSTEM FREQUENCY

The Alberta Interconnected Electric System (AIES) operates nominally at 60 Hz alternating current (AC). Frequency deviations are typically 59.5 to 60.5 Hz for small contingencies that cause modest disturbances, when the AIES remains intact and connected to the Western system.

4.2 VOLTAGE

The voltages on the EEDS are maintained within the range specified by CSA C235:19 - Preferred Voltage Levels for AC Systems 0 to 50,000 V as shown in Table 1 below.

TABLE 1

RECOMMENDED VOLTAGE VARIATION LIMITS FOR CIRCUITS UP TO 1,000 V, AT POINT OF CONNECTION[2]

NORMAL VOLTAGE	EXTREME OPERATION RANGE			
	MIN	NORMAL OPERATION RANGE		MAX
		MIN	MAX	
Single-phase systems				
1 phase, 3 wire, 120/240 V	106/212 V	110/220 V	125/250 V	127/254 V
1 phase, 2 wire, 240 V	212 V	220 V	250 V	254 V
1 phase, 2 wire, 480 V	424 V	440 V	500 V	508 V
1 phase, 2 wire, 600 V	530 V	550 V	625 V	635 V
Three-phase systems				
3 phase, 4 wire, 120/208 V	110/190 V	112/194 V	125/216 V	127/220 V
3 phase, 4 wire, 240/416 V	210/380 V	224/388 V	250/432 V	254/440 V
3 phase, 4 wire, 277/480 V	245/424 V	254/440 V	288/500 V	293/508 V
3 phase, 4 wire, 347/600 V	306/530 V	318/550 V	360/625 V	367/635 V
3 phase, 3 wire, 240 V, 480 V, 600 V	Refer to respective single-phase operating range			

[2] CSA C235:19, Table 2, the point of connection is the ownership boundary between the public power system and the customer facility

4.3 VOLTAGE UNBALANCE

The EEDS facilities are typically three-phase systems incorporating single-phase distribution taps. Under normal operating conditions, the voltage unbalance on EDTI's distribution system is limited to 3%. Voltage unbalance is calculated using the following formula derived from CAN/CSA-IEC 61000-4-30:16:

$$\textit{Voltage Unbalance (\%)} = 100 \times \frac{V_2}{V_1}$$

Where

V_2 is the negative-sequence voltage (fundamental frequency component)
V_1 is the positive-sequence voltage (fundamental frequency component)

4.4 FLICKER

Flicker can be defined as subjective impression of fluctuating luminance caused by voltage fluctuations.

There are two quantities to characterize the flicker severity. The parameter P_{st} for Perceptibility Short Term and P_{lt} for Perceptibility Long Term are used for comparing and planning the levels of voltage fluctuations and related light flicker.

The compatibility levels for flicker in LV/MV/HV systems are shown in Table 2[3] (see Section 6.12.3).

TABLE 2

COMPATIBILITY LEVELS FOR FLICKER IN LV/MV/HV SYSTEMS

	LV	MV	HV
PST	1.0	0.9	0.8
PLT	0.8	0.7	0.6

[3] Table 1 and 2 of CSA-C61000-3-7:09; Equation (1) of CSA-C61000-3-5:09

4.5 HARMONICS

Harmonics are sinusoidal voltages or currents having frequencies that are integer multiples of the frequency at which the supply system is designed to operate (termed the fundamental frequency; 60 Hz on the EEDS). Combined with the fundamental voltage or current, harmonics produce waveform distortion. Harmonic distortion exists due to the nonlinear characteristics of devices and loads on the power system.

The current and voltage distortion limits are shown in Table 3 and 4[4] (see Section 6.12.1).

TABLE 3

COMPATIBILITY LEVELS FOR INDIVIDUAL HARMONIC VOLTAGES IN LOW-VOLTAGE/MEDIUM-VOLTAGE NETWORKS (R.M.S. VALUES AS A PERCENTAGE OF R.M.S. VALUE OF THE FUNDAMENTAL COMPONENT)

ODD HARMONICS, NON- MULTIPLES OF 3		ODD HARMONICS, MULTIPLES OF 3†		EVEN HARMONICS	
Harmonic order, h	Harmonic voltage, %	Harmonic order, h	Harmonic voltage, %	Harmonic order, h	Harmonic voltage, %
5	6	3	6	2	2
7	5	9	3.5	4	1
11	3.5	15	2	6	0.5
13	3	21	1.5	8	0.5
17 ≤ h ≤ 49	2.27 x (17/h) – 0.27	21 < h ≤ 45	0.2	10 ≤ h ≤ 50	0.25 x (10/h) +0.25

† For both low-voltage networks and medium-voltage networks
‡ The levels given for odd harmonics that are multiples of three apply to zero-sequence harmonics. Also, on a three-phase network without a neutral conductor or without a load connected between line and ground, the values of the third and ninth harmonics can be much lower than the compatibility levels, depending on the unbalance of the system.

TABLE 4

HARMONIC LIMITS AS A PERCENTAGE OF FUNDAMENTAL RATED DER CURRENT

HARMONIC ORDER	ODD	EVEN
2nd through 10th	4.0%	1.0%
11th through 16th	2.0%	0.5%
17th through 22nd	1.5%	0.375%
23rd through 34th	0.6%	0.150%
35th through 40th	0.3%	0.075%

[4] CSA C22.3 No.9, Table B.3, Table B.4 and Table 19

4.6 FAULT LEVELS

Fault levels, including maximum allowable fault levels, vary significantly throughout the EEDS. The fault level can be up to 17.0 kA near its substations while the fault level can be lower than 1.0 kA near the ends of its circuits. These shall be considered in the design of the interconnection. Fault levels and X/R ratios shall be evaluated for the equipment selected. The limitation of fault current contribution from a DER is described in Section 6.12.

4.7 SYSTEM GROUNDING AND DISTRIBUTION TRANSFORMER CONFIGURATION

The EEDS is a 4-wire multi-grounded system. The winding configuration of distribution transformers on the 25 kV circuits are Yg-Yg while the winding configuration of the distribution transformers on the 15 kV circuits are typically D-Yg. The two types of transformer winding configurations have different impacts on the DER interconnection. For examples, see the transformer configuration impacts on temporary voltage and transient recovery voltage discussed in Sections 6.13.1 and 6.13.2.

4.8 AUTOMATIC CIRCUIT RECLOSING AFTER A FAULT

To maintain the reliability of the EEDS, EDTI uses automatic reclosing on some circuits that are primarily overhead. The reclosing time is usually 3 s after a breaker is tripped by a fault. However, the power producers should consult EDTI about the closing time on the circuits feeding the DERs. The power producers need to take into consideration line reclosing when designing DER protection schemes. This is to ensure that the DER is disconnected from EDTI's distribution system prior to the automatic reclosing of breakers or other devices.

5.0

DER Fundamentals

A DER system is composed of the DERs, interconnection systems, control systems, sensing devices or functions, and protection devices or functions up to the point of the DER connection (PoC).

5.1 DER TECHNOLOGIES

At a high level, DER technologies can include photovoltaics (PV), wind turbines, fuel cells, microturbines, reciprocating engines, combustion turbines, combined-heat and power (CHP), energy storage (ES) systems, etc. Only PV, CHP, fuel cell and ES are described briefly in this document as these DER technologies are expected to be prevalent on the EEDS in the foreseen future.

5.1.1 Photovoltaic

A Photovoltaic (PV) system is composed of one or more solar panels combined with an inverter and other electrical and mechanical hardware that use energy from the sun to generate electricity. PV systems can vary greatly in size from small rooftop or portable systems to massive utility-scale generation plants.

5.1.2 Combined-heat and power

Combined-heat and power (CHP), also known as cogeneration, produces both electricity and thermal energy on-site. CHP systems increase energy security by producing energy at the point of use, and significantly improve energy efficiency. The electricity is generated through synchronous generators or inverters.

5.1.3 Fuel cell

A fuel cell uses the chemical energy of hydrogen or other fuels to cleanly and efficiently produce electricity. The fuel cells generate direct currents which are regulated and converted AC through power conditioners (inverters).

Fuel cells cannot only be used for generating electricity but also be used for CHP for residential and commercial/industrial customers.

5.1.4 Energy storage

Energy storage (ES) is the capture of energy produced at one time for use at a later time. Distributed energy storage systems (DESS) applications include several types of battery, pumped hydro, compressed air, thermal energy storage, flywheels, etc. The interface device between an ES and EEDS is an inverter or a machine.

5.2 INTERFACE DEVICES BETWEEN EEDS AND DERS

The DERs discussed in Section 5.1 require interface equipment to tie in to the power grid. Generally speaking, there are two types of interface equipment, inverter-based and machine-based.

The inverter-based DERs have different electric characteristics than the machine-based DERs do, especially, the impact on effective grounding. Therefore, the two types of DERs should be studied differently.

5.2.1 Inverter-based DERs

Some of the above DER technologies generate power as direct current (DC) and need a method to convert DC to the AC used on the grid and in homes and businesses. Inverters convert DC to AC and allow PV, battery, and other DC sources tie in to EEDS.

5.2.2 Machine-based DERs

Some of the above DER technologies require machines to convert mechanical energy into electrical energy. The machines include synchronous generators and induction generators.

A synchronous generator is an alternator with the same rotor speed as the rotating magnetic field of the stator.

An induction generator is an alternator that utilizes an air gap rotating magnetic field between a stator and a rotor to interact with an induced current in a rotor winding. They are usually referred to as asynchronous generators. The generator speed is slightly higher than the synchronous speed. The output power increases or decreases with the slip rate. It can be excited by the power grid or self-excited with a power capacitor.

5.3 MOMENTARY CLOSED TRANSITION SWITCHING

A DER system can be connected to the EEDS momentarily (≤ 100 ms) with the purpose of transferring load from the EEDS to the DER and then operating in stand-alone (emergency) mode or transferring load from the DER back to the EEDS.

5.3.1 Momentary closed transition switching of a standby DER

A standby/emergency DER is a customer-owned backup generation used during an outage on the circuit serving the customer.

5.3.2 Microgrid and intentional islands

A microgrid is defined as a group of interconnected loads and distributed energy resources with clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. A microgrid can connect and disconnect from the grid to enable it to operate in both grid-connected or island mode[5].

A microgrid or an intentional island generally operates while connected to the EEDS, but importantly, it can break off and operate on its own using local energy generation in times of crisis, like storms or power outages, or for other reasons. When power on the EEDS is restored, the microgrid or the intentional island can run in parallel to the EEDS.

When operating in a microgrid or an intentional island, participating DERs might have to adjust several control and protection settings. These alternate settings and ranges of adjustability shall be enabled only when the intentional island is isolated from the EEDS. In order to meet this requirement, adaptive protection and control settings may be required by EDTI.

[5] 2030.7-2017 - IEEE Standard for the Specification of Microgrid Controllers

The protection requirements for microgrids or intentional islands are shown in Section 7 except anti-islanding protection. Additional protection requirements for islanding operation will be specified on a case-by-case basis.

5.4 GRADES OF DER FOR SYSTEM INTERCONNECTION CAPABILITIES

An increasing penetration of DER within the EEDS has driven the need for a limited set of specific DER performance characteristics in this Technical Requirements, particularly with regards to the following:

- Participation of the DER in the voltage and reactive power management of the EEDS in normal operations
- Voltage and frequency disturbance ride-through capabilities necessary to protect bulk power system security and EEDS power quality in abnormal operations

CSA C22.3 No. 9:20 requires that the wires owner for a particular PCC of the DER system interconnection shall specify the applicable grade of DER system interconnection capability, either a baseline or supplemental grade, based on assessed level of DERs penetration low or high respectively, and the DER technology (inverter based, synchronous, or induction).

The high DER penetration level, based on DER adoption experience in the U.S. and elsewhere, appears to be when DER penetration reaches beyond about 5% of distribution grid peak loading system-wide. This level of penetration typically results in pockets of high customer adoption in some neighbourhoods and commercial districts, which creates the need for enhanced functionality.

Performance grades specify minimum equipment capability requirements, and specify designated limiting requirements for ranges of allowable settings of control or trip parameter values. Section 8 will specify the settings for DERs as different grades to respond to abnormal conditions on EDTI system. Table 5 provides recommendations for determining DER system interconnection grade capabilities.

TABLE 5

RECOMMENDED CRITERIA TO DETERMINE DER SYSTEM INTERCONNECTION GRADE CAPABILITIES[6]

DER TYPE	PENETRATION LEVEL	INTERCONNECTION GRADE CAPABILITIES
Inverter interfaced generators, doubly fed induction generators and new technologies	Low	Baseline
	High	Supplemental
Synchronous generators	Any	Baseline
Induction generators	Any	Baseline

[6] CSA C22.3 No. 9:20, Table 3

6.0

General Specifications and Performance Requirements for DER Interconnection

The performance requirements apply to interconnection of either:

- a single DER unit based on that unit's rating, or
- multiple DER units based on the aggregate rating of all the DER units that are within a site.

The capabilities and functions of the DER hardware and software that affect the circuit are required to meet this Technical Requirement regardless of their location on the EEDS. The performance requirements in this Technical Requirement are functional and do not specify any particular equipment or equipment type.

The technical specifications and performance requirements specified in this Technical Requirement are needed for interconnection and interoperability of DER and will be sufficient for most installations.

6.1 DER CERTIFICATION AND CAPABILITY REQUIREMENTS

6.1.1 Inverter-based DERs

When a power producer applies for DER interconnection to the EEDS, any inverters interconnected to the EEDS shall comply with UL 1741 or the latest version of UL 1741 and CSA C22.3 No.9 when a power producer applies for DER interconnection to the EEDS, including but not limited to the functions listed below.

- Voltage and frequency disturbance ride-through
- Active voltage support (volt-var, volt-watt, watt-var, constant reactive power, etc.)
- Communication with Distributed Energy Resource Management Systems (DERMS) through local DER communication interface
- Real power reduction or curtailment

6.1.2 Machine-based DERs

The machine-based DERs shall have the functions listed in Section 6.1.1 and have them demonstrated through interconnection tests.

6.2 MEASUREMENT ACCURACY

Each DER shall meet the minimum steady-state and transient measurement and calculation accuracies for the following parameters:

a. voltage (RMS);

b. frequency;

c. active power;

d. reactive power, and

e. time.

These requirements are specified in Table 6. Actual measurement and calculation accuracies for a DER shall be stated for each of these parameters.

TABLE 6[7]

MINIMUM MEASUREMENT AND CALCULATION ACCURACY REQUIREMENTS FOR DER*

PARAMETER	STEADY-STATE MEASUREMENTS			TRANSIENT MEASUREMENTS		
	MIN MEASUREMENT ACCURACY	MEASUREMENT WINDOW	RANGE	MIN MEASUREMENT ACCURACY	MEASUREMENT WINDOW	RANGE
Voltage (RMS)	± 1% V_{nom}	12 cycles	50% to 120%	± 2% V_{nom}	5 cycles	50% to 120%
Frequency†	10 mHz	60 cycles	50 to 66 Hz	100 mHz	5 cycles	50 to 66 Hz
Active power	± 5% rated apparentpower	12 cycles	20% to 100%	N/A	N/A	N/A
Reactive power	± 5% rated apparent power	12 cycles	20% to 100%	N/A	N/A	N/A
Time	1% of measured duration	N/A	5 s to 600 s	2 cycles	N/A	100 ms to 5 s

* Measurement accuracy requirements are applicable for voltage THD < 2.5% and individual voltage harmonics <1.5%.
† Frequency accuracy requirements are applicable only when the fundamental voltage is greater than 30% of the nominal voltage.

6.3 MEASUREMENT POINT

The measurement point is the location where the DER system measures power system quantities for the purpose of implementing the protection and control functions required by this TR. The measurement location shall be determined by the characteristics of the DER and Local EPS as described in Section 4.2 of IEEE Std. 1547-2018.

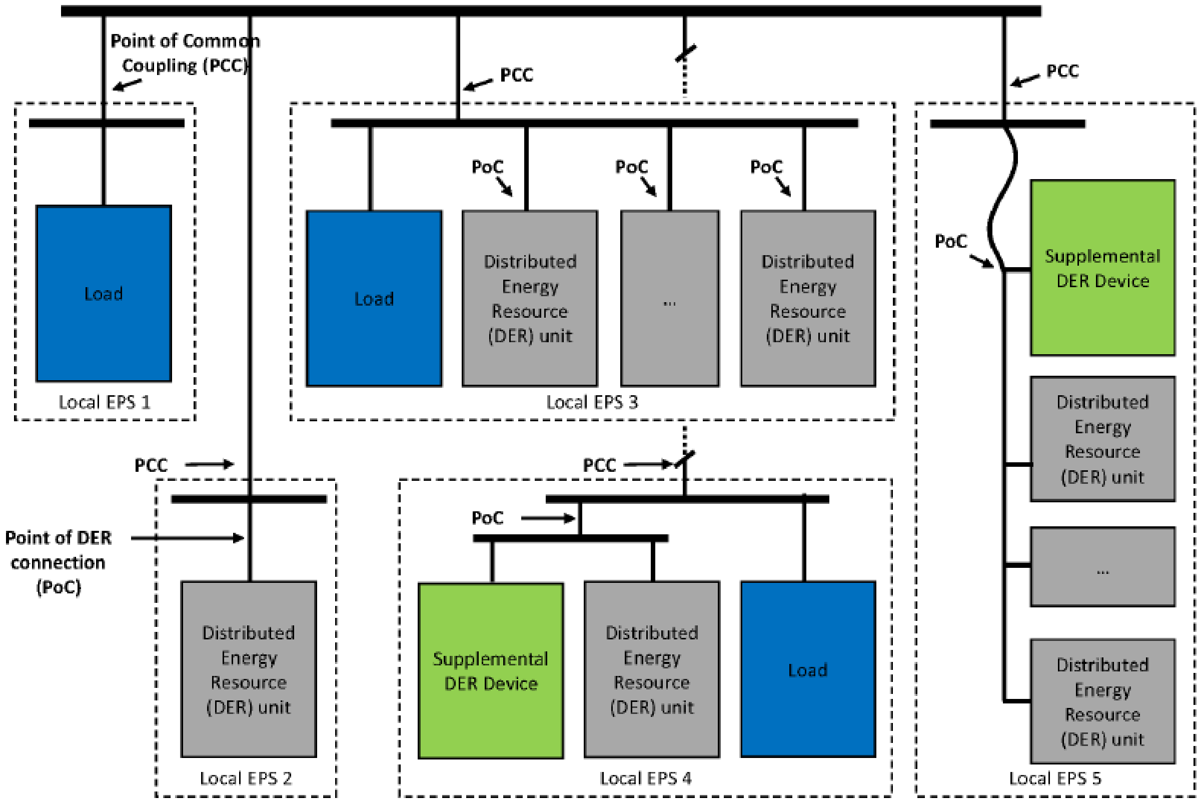
Figure 1 shows the PCC and PoC examples on the EEDS.

[7] CSA C22.3 No. 9:20, Table 1

FIGURE 1

DER SYSTEM SET UP AND INTERCONNECTION TERMINOLOGY[8]

(See Sections 6.10, 7, 8.2.1, 14.2)



The requirements for the DER on each site vary as shown below.

- The example Site 1 (Local EPS 1) includes only load. Any requirements for this site are outside the scope of this TR.
- The example Site 2 (Local EPS 2) includes only DER. Depending on the DER rating, requirements of this Technical Requirement apply either at the PCC or the PoC. The DER unit in this example is able to meet requirements at its terminals without any supplemental DER device; the PoC coincides with the DER unit's terminals.
- The example Site 3 (Local EPS 3) includes both DER units and load. Depending on the aggregate DER units' rating and the percent of average load demand, requirements of this Technical Requirement apply either at the PCC or the PoC. The two (or more) DER units are able to meet requirements at its terminals without any supplemental DER device; the PoC coincides with the DER units' terminals; there are two (or more) PoCs.

[8] IEEE Std. 1547-2018, Figure 2

- The example Site 4 (Local EPS 4) includes a DER unit, a supplemental DER device, and load. Depending on the DER unit's rating and the percent of average load demand, requirements of this Technical Requirement apply either at the PCC or the PoC. The DER unit is not able to meet requirements at its terminals without any supplemental DER device; the PoC is the point where the requirements of this Technical Requirement are met by the DER unit in conjunction with the supplemental DER device exclusive of any load, if present, in the respective part of the site.
- The example Site 5 (Local EPS 5) includes two (or more) DER units and a supplemental DER device but no load. Depending on the aggregate DER units' rating, requirements of this Technical Requirement apply either at the PCC or the PoC. As indicated by the curved line, the PCC and PoC may be located well apart from each other. The two (or more) DER units are not able to meet requirements at their terminals without any supplemental DER device; the PoC is the point where the requirements of this Technical Requirement are met by two (or more) DER units in conjunction with the supplemental DER device exclusive of any load, if present, in the respective part of the site.

6.4 REFERENCE POINTS OF APPLICABILITY (RPA)

The characteristics of the Local EPS and DER shall determine the reference point of applicability (RPA). The RPA for all performance requirements of this Technical Requirement shall be the PCC. Alternatively, for Local EPSs where zero sequence continuity[9] between the PCC and PoC is maintained and either of the following conditions apply, the RPA for performance requirements of this Technical Requirement can be the PoC:

a. Aggregate DER nameplate rating of equal to or less than 500 kVA, or

b. Annual average load demand as calculated by EDTI of greater than 10% of the aggregate DER nameplate rating, and where the Local EPS is not capable of, or is prevented from, exporting more than 500 kVA for longer than 30 s.

For all other Local EPSs meeting either of the conditions a) or b) above but not meeting the requirement for zero sequence continuity, the RPA for performance requirements other than the response to abnormal conditions on the EEDS shall be the PoC.

6.5 APPLICABLE VOLTAGES

The applicable voltages determine the performance of a Local EPS or DER and are the electrical quantities specified with regard to the measurement point, individual phase-to-neutral, phase-to-ground, or phase-to-phase combination and time resolution.

[9] When the zero sequence continuity is broken, for example by a delta-wye transformer between the PCC and the PoC, the voltages at the PoC may not be representative of the voltages at the PCC under abnormal voltage conditions. Examples of issues created by this condition include the following:
- Difficulty of 'sensing' single-phase-to-ground faults or failure to detect ground-fault overvoltages.
- Detecting abnormal voltage conditions when a DER back-feeds into the grid during a balanced open-phase condition.
- Ability of detecting open-phase on the EEDS by the DER is diminished.

For DER with a PCC located at the medium-voltage level, the applicable voltages shall be determined by the configuration and nominal voltage of the EEDS at the PCC. For DER with a PCC located at the low-voltage level, the applicable voltages shall be determined by the configuration of the low-voltage winding of the distribution/interface transformer(s) between the medium-voltage system and the low-voltage system.

The applicable voltages that shall be detected are shown in Table 7 and Table 8. For multi-phase systems, the requirements for applicable voltages shall apply to all phases.

TABLE 7

APPLICABLE VOLTAGES WHEN PCC IS LOCATED AT MEDIUM VOLTAGE[10]

SYSTEM CONFIGURATION AT PCC	APPLICABLE VOLTAGES
Three-phase, four-wire	Phase-to-phase and phase-to-neutral
Three-phase, three-wire, grounded	Phase-to-phase and phase-to-ground
Three-phase, three-wire, ungrounded	Phase-to-phase
Single-phase, two-wire	Phase-to-2nd wire (the 2nd wire may be either a neutral (or a 2nd phase)

TABLE 8

APPLICABLE VOLTAGES WHEN PCC IS LOCATED AT LOW VOLTAGE[11]

LOW-VOLTAGE WINDING CONFIGURATION OF DISTRIBUTION/INTERFACE TRANSFORMER(S)*	APPLICABLE VOLTAGES
Grounded Wye, Tee or Zig-Zag†	Phase-to-phase and phase-to-neutral or Phase-to-phase and phase-to-ground
Ungrounded Wye, Tee or Zig-Zag	Phase-to-phase and phase-to-neutral
Delta††	Phase-to-phase
Single-phase 120/240 V (split-phase or Edison connection)	Line-to-neutral for 120 V DER units, Line-to-line for 240 V DER units¶

* A three-phase transformer or a bank of single-phase transformers may be used for three-phase systems.
† For 120/208 V two-phase services, line-to-line voltages shall be sufficient.
†† Including delta with mid tap connection (grounded or ungrounded).
¶ Sensing line-to-neutral on both legs of a 120/240 V split-phase or Edison connection effectively senses the lint-to-line and is therefore compliant with this requirement. Sensing line-to-ground may also be used. However, the ground connection should only be used for voltage sensing purposes.

[10] IEEE Std. 1547-2018, Table 1
[11] IEEE Std. 1547-2018, Table 2

6.6 CEASE TO ENERGIZE PERFORMANCE REQUIREMENT

In the cease to energize state, the DER shall not deliver active power during steady-state or transient conditions. The requirements for cease to energize shall apply to the PoC. For a DER system with aggregate DER rating less than 500 kVA, the reactive power exchange shall be less than 10% of nameplate DER rating and shall exclusively result from passive devices. For a DER system with aggregate DER rating 500 kVA and greater, the reactive power exchange shall be less than 3% of nameplate DER rating and shall exclusively result from passive devices.

Alternatively, the requirements for cease to energize may be met by disconnecting the DER from the distribution system. The DER may continue to deliver power to the portion of the power producer's facility, which is disconnected from the distribution system.

6.7 CONTROL CAPABILITY REQUIREMENTS

A DER shall be capable of responding to external inputs which may come through a manual DER control panel or through the local DER communication interface (see Section 9 for detail information about control capability requirements).

6.7.1 Capability to disable permit service

A DER shall be capable of disabling the permit service setting and shall cease to energize the EEDS and trip in no more than 2 s.

6.7.2 Capability to limit active power

A DER shall be capable of limiting active power as a percentage of the nameplate active power rating. The DER shall limit its active power output to not greater than the active power limit set point in no more than 30 s or in the time it takes for the primary energy source to reduce its active power output to achieve the requirements of the active power limit set point, whichever is greater. In cases where the DER is supplying local loads at the same site, the active power limit set point may be implemented as a maximum active power export to the EEDS. Under mutual written agreement between EDTI and the power producer, the DER may be required to reduce active power below the level needed to support local loads.

DER power curtailment occurs when the DER power producers are required to decrease their output power in order to maintain the operational limits of the EEDS. The DER curtailment will be evaluated while considering both technical and economic aspects because it may not be feasible to invest in adding new DER units and then curtailing its added power for long durations.

6.7.3 Execution of mode or parameter changes

Transition between modes shall commence in no more than 30 s after the mode setting change is received at the local DER communication interface. Changes of control functional modes shall be executed such that the DER output is transitioned smoothly over a time period between 5 s and 300 s.

Ramping of DER output is not required for control parameter setting changes. For all control and protective function parameter settings, the time following the input to the local DER communication interface and preceding the point in time when the invoked action begins shall be no greater than 30 s.

6.8 PRIORITIZATION OF DER RESPONSES

Requirements set forth in Sections 6.10 and 8 shall be prioritized as follows:

a. The response to disabling permit service setting specified in Section 6.7.1 shall take precedence over any requirements within Sections 6.10 and 8.

b. DER tripping requirements specified in Sections 7.3, 8.2.1 and 8.3.1 shall take precedence over any other requirements within Sections 6.10 and 8, subject to the following:

   i. Where the prescribed trip duration settings for the respective voltage or frequency magnitude are set at least 160 ms or 1% of the prescribed tripping time, whichever is greater, beyond the prescribed ride-through duration, the DER shall comply with the ride-through requirements specified in Sections 8.2.2 and 8.3.2 prior to tripping.

   ii. In all other cases, the ride-through requirements shall apply until 160 ms or 1% of the prescribed tripping time, whichever is greater, prior to the prescribed tripping time.

c. DER ride-through requirements specified in Sections 8.2.2 and 8.3.2 shall take precedence over all other requirements within Sections 6.10 and 8 with the exception of tripping requirements listed in item b) above. Ride-through may be terminated by the detection of an unintentional island specified in Section 7.6. However, false detection of an unintentional island that does not actually exist shall not justify non-compliance with ride-through requirements. Conversely, ride-through requirements specified in Section 8 shall not inhibit the islanding detection performance specified in Section 7.6 where a valid unintentional islanding condition exists.

d. The voltage-active power mode requirements specified in Section 6.11.2 and frequency-droop (frequency power) response requirements specified in Section 6.11.3 shall take precedence over all other requirements within Sections 6.10 and 8, with the exception of tripping and ride-through requirements listed in item b) and item c) above. If both voltage-active power and frequency-droop modes are active, the lesser of the power value shall take precedence.

e. The response to active power limit signal specified in Section 6.7.2 shall take precedence over all other requirements within Sections 6.10 and 8, with the exception of tripping and ride-through requirements listed in item b) and item c) above, and voltage-active power mode requirements and frequency-droop response requirements listed in item d).

f. The voltage regulation functions specified in Section 6.10.4 shall take precedence over any remaining requirements within Sections 6.10 and 8.

6.9 INADVERTENT ENERGIZATION OF THE EEDS

The DER shall not energize the EEDS when the EEDS is de-energized (see Section 7.6 for detail information about anti-islanding).

6.10 ACTIVE VOLTAGE REGULATION REQUIREMENTS AT PCCS

The DER system shall be capable of voltage regulation at the PCC via DER system autonomous reactive power control. For the DER system to actively participate in voltage regulation at PCC, it shall first be approved by EDTI.

The DER system shall be capable of PCC voltage control provision by following DER system autonomous, mutually exclusive reactive power, Q, control functions, as follows:

- adjustable constant power factor (ACPF) control function;
- adjustable constant reactive power (ACQ) control function;
- reactive power as function of voltage [Q(V)] control function; and
- reactive power as function of active power [Q(P)] control function.

The DER system shall be capable of activation of these control functions one at a time.

The power producer shall be responsible for implementing setting modifications and control function selections, as specified by EDTI. Under mutual written agreement between EDTI and power producer, reactive power control functions and their implementations other than the ones listed above and further described below shall be permitted. The default control function enabled shall be adjustable constant power factor control with a power factor set point of 1.0.

6.10.1 Reactive power capabilities

DER systems shall be capable of sourcing (injecting, over-excited, capacitive) and consuming (absorbing, under-excited, inductive) reactive power, Q, up to levels within the range of values as specified in Table 9 at all PCC feed-in active power, P, levels from 20% of corresponding DER nameplate kVA rating and onward.

TABLE 9

MINIMUM DER SYSTEM REACTIVE POWER CAPABILITIES[12]

GRADES OF DER SYSTEM INTERCONNECTION CAPABILITIES	SOURCING (CAPACITIVE) CAPABILITY AS % OF AS NAMEPLATE APPARENT POWER, S (KVA) RATING	CONSUMPTION (INDUCTIVE) CAPABILITY AS % OF AS NAMEPLATE APPARENT POWER, S (KVA) RATING
Baseline grade	44% at PCC nominal voltage	25% at PCC nominal voltage
Supplemental grade	44% over +/- 5% of PCC nominal voltage range	44% over +/- 5% of PCC nominal voltage range

[12] CSA C22.3 No.9:20, Table 4

6.10.2 Adjustable constant power factor (ACPF) control function

When the ACPF control function of the DER system is specified, the DER system shall operate at a constant power factor at all feed-in active power, P, levels. The power factor control setting shall be specified by EDTI provided the power factor settings implies reactive power sourcing or consuming within the minimum DER system reactive power capability requirement in accordance with Table 9. The power factor settings may be adjusted locally and/or remotely. The maximum DER system response time to a settings change or voltage disturbance shall be 3 s or less.

6.10.3 Adjustable constant reactive power (ACQ) control function

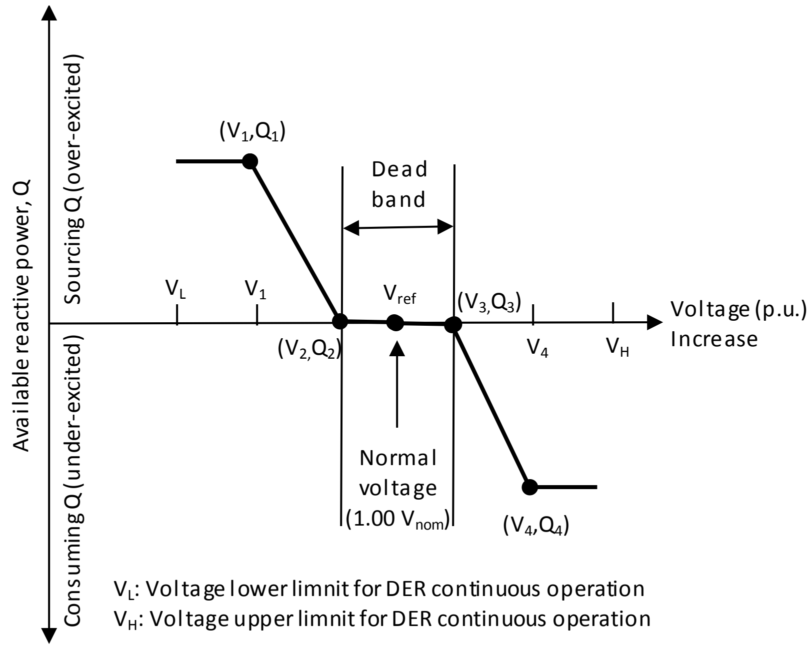
When the ACQ control function of the DER system is specified, the DER system shall provide constant reactive power at all feed-in active power levels. The reactive power level and operating mode (sourcing Q or consuming Q) shall be specified by EDTI and shall be within the minimum DER system reactive power capability requirement in accordance with Table 9. The reactive power settings may be adjusted locally and/or remotely. The maximum DER system response time to a settings change or voltage disturbance shall be 10 s or less.

6.10.4 Reactive power as function of voltage control function

When the Q(V) control function of the DER system is specified, the DER system shall actively and autonomously control its reactive power provision as a function of voltage at the PCC following a Q as function of V or Q(V) piecewise linear characteristic. One example of such Q(V) characteristic is shown in Figure 2. The characteristic shall be configured in accordance with the default parameter values specified in Table 10 for the given DER system type, baseline, or supplemental type. The characteristic may also be configured as specified by the wires owner using the values between minimum and maximum in the adjustable range columns. The Q(V) characteristic parameters may be adjusted locally and/or remotely.

FIGURE 2

EXAMPLE OF PIECEWISE LINEAR Q AS FUNCTION OF V OR Q(V) CHARACTERISTICS[13]



[13] CSA C22.3 No.9:20, Figure 2

TABLE 10

VOLT-VAR PARAMETER SETTINGS FOR BASELINE AND SUPPLEMENTAL DER SYSTEM TYPES[14]

VOLT-VAR PARAMETER LABELS	PARAMETER DESCRIPTION	DEFAULT VALUES FOR BASELINE DER SYSTEMS	DEFAULT VALUES FOR SUPPLEMENTAL DER SYSTEMS	ADJUSTABLE RANGE	
				MINIMUM	MAXIMUM
V_{ref}	Reference voltage	Normal voltage V_{nom}	Normal voltage V_{nom}	0.95 V_{nom}	1.05 V_{nom}
V_2	Dead band lower voltage limit	Normal voltage V_{nom}	V_{ref} – 0.02 V_{nom}	Baseline: V_{ref} Suppl:V_{ref} – 0.03 V_{nom}	V_{ref}
Q_2	Reactive power, Q, sourcing or consumption at voltage V_2	0	0	100% of DER system reactive power capability, consumption	100% of DER system reactive power capability, sourcing
V_3	Dead band upper voltage limit	V_{nom}	V_{ref} + 0.02 V_{nom}	V_{ref}	Baseline: V_{ref} Suppl: V_{ref} + 0.03 V_{nom}
Q_3	Reactive power, Q, sourcing or consumption at voltage V_3	0	0	100% of nameplate reactive power capability, absorption	100% of DER system reactive power capability, sourcing
V_1	Voltage at which DER system shall source Q_1 reactive power	0.9 V_{nom}	V_{ref} – 0.08 V_{nom}	V_{ref} − 0.18 V_{nom}	V2 − 0.02 V_{nom}
Q_1	Reactive power, Q, sourcing or consumption at voltage V_1	44% of nameplate kVA	44% of nameplate kVA	0	100% of DER system reactive power capability, sourcing
V_4	Voltage at which DER system shall source Q_4 reactive power	1.1 V_{nom}	V_{ref} + 0.08 V_{nom}	V3+0.02 V_{nom}	V_{ref} + 0.18 V_{nom}
Q_4	Reactive power, Q, consumption at voltage V_4	25% of nameplate kVA	44% of nameplate kVA	100% of DER system reactive power capability, consumption	0
Response time	Time to 90% of the reactive power, Q, change in response to the change in voltage	5.0 sec	2.5 sec	0.5 sec	60 sec

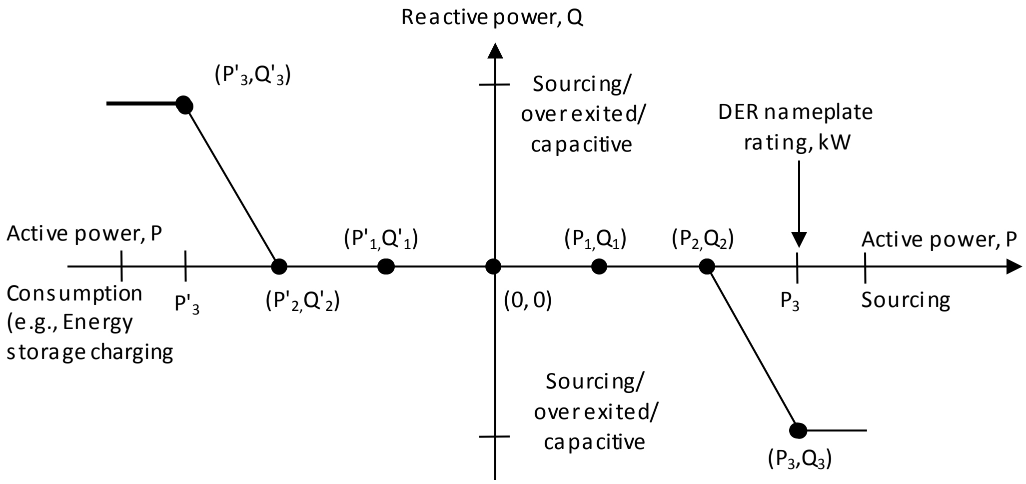
[14] CSA C22.3 No.9:20, Table 5

6.10.5 Reactive power as function of active power control function

In the Q(P) control function mode of operation, the DER shall actively control the reactive power output as a function of the active power feed-in following a target piecewise linear reactive power as function of active power [Q(P)] feed-forward characteristic (without controller intentional time delay). In no case shall the response time be greater than 10 s. Example of Q (P) characteristic is shown in Figure 3. The target characteristic shall be configured in accordance with the default parameter values specified in Table 11. The Q(P) characteristics may be configured as specified by EDTI using the values specified in the optional adjustable range. The left-hand side of Figure 3 and corresponding requirements specified in Table 10 shall apply only to DERs capable of absorbing active power (e.g., battery energy storage based DERs).The Q(P) characteristics may be adjusted locally and/or remotely as specified by EDTI.

FIGURE 3

EXAMPLE OF PIECEWISE LINEAR Q(P) CHARACTERISTICS[15]



[15] CSA C22.3 No.9:20, Figure 3

TABLE 11

WATT-VAR PARAMETER SETTINGS FOR BASELINE AND SUPPLEMENTAL DER SYSTEM TYPES[16]

WATT- VAR PARAMETERS LABELS	DEFAULT VALUES FOR BASELINE DER SYSTEMS	DEFAULT VALUES FOR SUPPLEMENTAL DER SYSTEMS	ADJUSTABLE RANGE	
			MINIMUM	MAXIMUM
P_3	P_{rated}*		$P_2 + 0.1P_{rated}$	P_{rated}
P_2	0.5 P_{rated}		$0.4P_{rated}$	$0.8P_{rated}$
P_1	The greater of 0.2 P_{rated}* and P_{min}†		P_{min}	$P_2 - 0.1P_{rated}$
P_1§	The greater of 0.2 x P'_{rated}‡ and P_{min}††		$P'_2 - 0.1P'_{rated}$ P'_{rated}	P'_{min}
P_2	0.5 P_{rated}		$0.8P_{rated}$	$0.4P_{rated}$
Q_3	P_{rated}		P_{rated}	$P_2 + 0.1P_{rated}$
Q_2	25% of nameplate apparent power rating, consumption	44% of nameplate apparent power rating, consumption	100% of nameplate reactive power, Q, consumption capability	100% of nameplate reactive power, Q, sourcing capability
Q_1	0			
Q'_1	0			
Q'_2	0			
Q'_3	44% of nameplate kVA, sourcing			

* *P* rated is the DER active power nameplate rating.
† *P* min is the DER's minimum active power output.
‡ *P'* rated is the maximum active power that the DER can consume/absorb
§ *P'* parameters are negative in value.
†† *P'* min is the minimum active power that DER can consume/absorb

[16] CSA C22.3 No.9:20, Table 6

6.11 ACTIVE POWER CONTROL REQUIREMENTS

All DER systems shall be capable of limiting active power as a percentage of the nameplate active power rating by following the active power limit set point, either as a fixed set point entry or continuously supplied power limit signal from external controller with a delay of no more than 30 s or in the time it takes for the primary energy source to reduce its active power output.

In cases where the DER is supplying loads in the power producer's facility, the active power limit set point may be implemented as a maximum active power export to the distribution system. Under mutual agreement between EDTI and the DER operator, the DER might be required to reduce active power below the level needed to support loads in the power producer's facility.

6.11.1 DER active power rate of change, P(t)

All DER systems shall be capable of controlling rate of change of active power injection to the distribution system. The average rate of change of active power (W/sec) shall be adjustable from 1% of the rated DER power per second to the maximum capable rate of change of the DER. The power ramp shall be linear or piecewise linear such that the average slope satisfies the ramp setting.

In response to an initial connect to the distribution system or in response to a reconnect (recovery from an abnormal distribution system condition), the DER shall increase injection of active power at a default rate of 2% of rated power per second. Other ramp rates might be required by EDTI at time of commissioning.

6.11.2 Active power as a function of voltage control function (voltage-active power mode)

All DER systems shall provide for preset PCC voltage control capability via limiting or curtailing the active power feed-in. The default setting for this function shall be "disabled". Enabling/disabling this function is at the discretion of EDTI.

When the active power as a function of voltage control function is enabled, the DER system shall actively limit the DER maximum active power output as a function of the voltage following an active power, P, as function of voltage, V or P(V), piecewise linear characteristic. Two examples of these P(V) piecewise linear characteristics are shown in Figure 4. The characteristic shall be configured in accordance with the default parameter values specified in Table 12 for the given DER power flow operating range, either uni-directional or bi-directional (e.g., storage DER systems). The characteristic may be configured as specified by EDTI using the values in the adjustable range. The characteristics curves may be adjusted locally and/or remotely as specified by EDTI.

FIGURE 4

EXAMPLES OF PIECEWISE LINEAR P(V) CHARACTERISTICS[17]

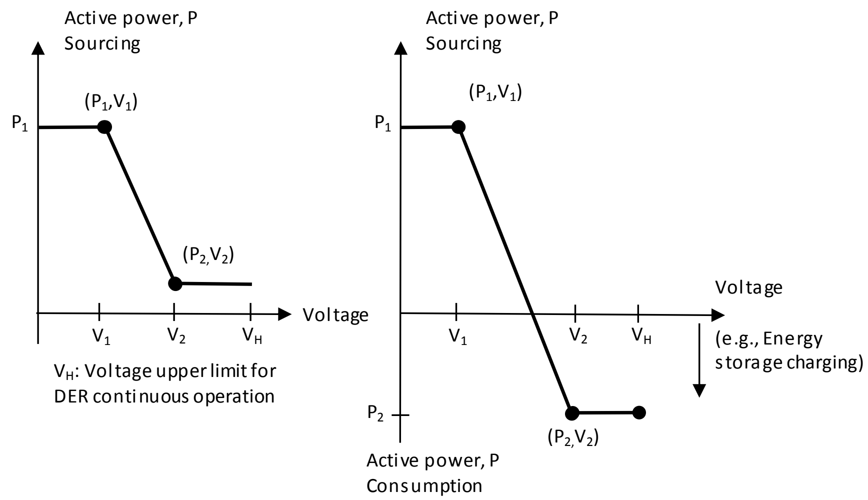


TABLE 12

P(V) OR VOLT-WATT PARAMETER SETTINGS FOR DER SYSTEMS[18]

P(V) PARAMETER LABELS	DEFAULT PARAMETER VALUES FOR DER SYSTEMS	RANGES OF ALLOWABLE SETTINGS	
		MINIMUM	MAXIMUM
V_1	1.06 V_{nom}	1.05 V_{nom}	1.09 V_{nom}
P_1	P_{rated}	N/A	N/A
V_2	1.1 V_{nom}	V_1 + 0.01 V_{nom}	1.10 V_{nom}
P_2 (unidirectional, sourcing active power DER system)	The lesser of 0.2 P_{rated} or P_{min}*	P_{min}	P_{rated}
P'_2 (bi-directional, sourcing and consuming or storing active power DER systems)	0	0	P'_{rated}†
Response Time	5 sec‡	0.5 sec	60 sec

* P_{min} is the minimum continuous active power output of the DER system.
† P'_{rated} is the maximum active power that DER can consume/absorb.
‡ Any response time setting of less than 10 s shall be in agreement with EDTI due to potential that lower setting can cause dynamically unstable system behaviour.

[17] CSA C22.3 No.9:20, Figure 4
[18] CSA C22.3 N0.9:20, Table 7

6.11.3 System frequency support via active power control (frequency droop)[19]

When the system frequency support via active power control function mode of operation is enabled, the DER system shall actively control the active power, P, output as a function of the system frequency, F, following a target linear droop (active power as function of system frequency or P as f(F)) without controller intentional time delay. The droop shall be adjustable between 3% and 7% and set at 5% unless otherwise specified by EDTI. The frequency dead-band shall be adjustable between 0 mHz and 100 mHz and set to 36 mHz unless otherwise specified by EDTI.

DER systems running at full power and renewable DERs will not be expected to contribute more active power when frequency declines nor will units at minimum power be expected to contribute less active power when frequency increases.

For DER systems that do not absorb active power (non-storage DER systems), Pmin (the minimum set point for active power generation due to overfrequency) is subject to the equipment capability. For DER systems that can source and absorb active power, P_{min} and P_{max} (the maximum set point for active power absorption and injection, respectively, due to system over/under frequency) are subject to equipment capabilities.

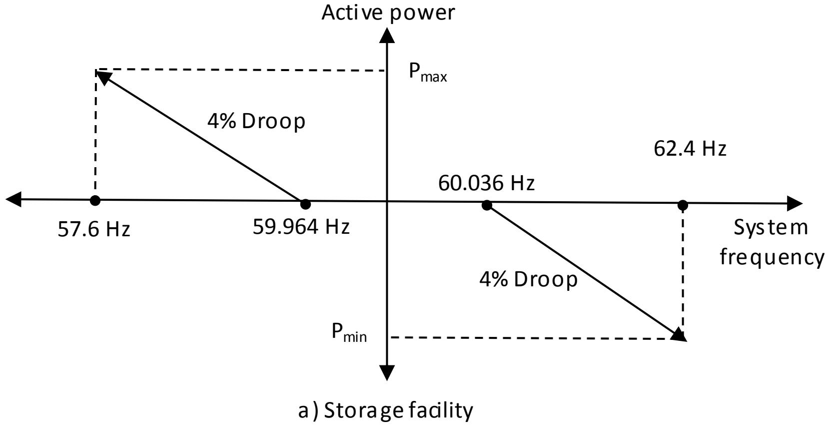
Two examples of active power as function of system frequency, P as f (F) characteristic of a solar DER (Figure 5 a) and a storage facility (Figure 5 b) are shown below.

EDTI will determine when the frequency droop function is enabled by coordinating with AESO.

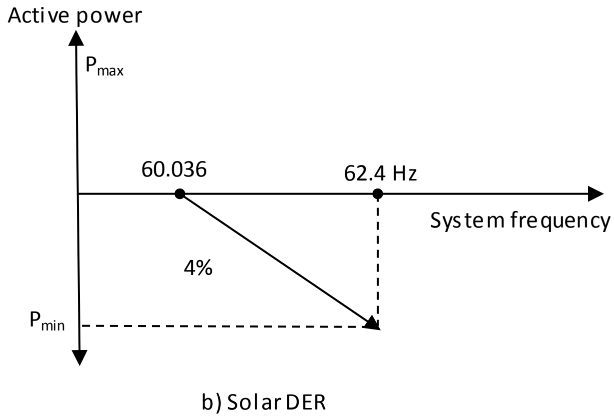
[19] Ride-Through Performance Recommendations by AESO, March 2021

FIGURE 5

EXAMPLES OF PIECEWISE LINEAR P (V) CHARACTERISTICS[20]



a) Storage facility



b) Solar DER

6.12 POWER QUALITY

6.12.1 Harmonics

The DER system shall not inject harmonic current such that it causes objectionable voltage distortion on the EEDS. The DER system shall comply with harmonic limits as a percent of fundamental rated DER current specified in Table 4.

Harmonic current injections shall be exclusive of the harmonic currents that are due to harmonic voltage distortion present in the distribution system when the DER system is not connected.

It is the power producer’s responsibility to implement corrective measures (e.g., adding harmonic filters) in cases where the projected or actual voltage harmonics at PCC upon DER interconnection exceed the values of voltage harmonics in LV grids or voltage harmonics in MV grids as shown in Table 3.

[20] CSA C22.3 No.9:20, Figure 5

6.12.2 DC current injection

The DER system shall not inject at the point of DER connection a DC current greater than 0.5% of the DER system rated output current.

6.12.3 Flicker

Flicker limits for DER connection to EEDS at low and medium voltage shall occur as specified in Table 2.

6.12.4 Undervoltage and overvoltage

DERs can help mitigate undervoltage issues on the EEDS if their active voltage regulation controls are set properly.

When DER penetration is high on a circuit level, the voltages on some segments on the circuit can exceed the upper limits, 125 V for normal operation and 127 V for contingency operation on a 120 v base, specified by CSA C235:19.

If the voltage at a PCC exceeds the above limits, the DER(s) must regulate the voltage based on the functions discussed in Section 6.6. Otherwise, the DER(s) will be tripped off by overvoltage protection as discussed in Section 8.2.1.

6.12.5 Resonance and self excitation

The potential effects of resonance should be considered as part of the design and review of the DER system. These include:

a. ferroresonance in the transformer;

b. sub-synchronous resonance due to the presence of capacitor banks or large rotating machines; and

c. harmonic resonance with other customers when capacitors are being added as part of the installation (based on information provided by EDTI). When induction generators are used, the potential for self-excitation should be assessed and addressed.

6.13 EFFECTIVE GROUNDING

Effective grounding is a characteristic of electric power systems for limiting ground fault overvoltage and considered in coordination of fault current protective devices. Adding DER can affect power system grounding.

IEEE C62.92.1 states that effective grounding “is obtained approximately when, for all system conditions, the ratio of the zero-sequence reactance to the positive-sequence reactance, (X_0/X_1) is positive and ≤ 3, and the ratio of zero-sequence resistance to positive-sequence reactance, (R_0/X_1) is positive and < 1”. However, on 4-wire multi-grounded neutral power distribution systems, good design practice per IEEE C62.92.4 implies that the coefficient of grounding (COG) should be about 72% or less where possible (roughly $R_0/X_1 \leq 0.7$ and $X_0/X_1 \leq 2$).

In IEEE C62.92.1, the COG calculation was simplified assuming the same positive sequence and negative sequence impedances ($Z_1 = Z_2$). This assumption is generally true for machine-based DERs, lines, cables and transformers, but it does not hold for inverters that are current sources and have high sequence impedances. Therefore, these impedance ratios generally cannot provide a good approximation when inverters are the dominant sources.

Where inverter-based DERs are the dominant sources of energization of an isolated sub-circuit, the aggregate rated power output of the sources does not greatly exceed the minimum load of the sub-circuit, and the majority of the load is phase-to-ground connected (this is true for circuits with majority of residential customers), supplemental ground sources are not necessary to maintain effective grounding.

Where the generation to load ratio is high, a supplemental ground source may significantly reduce the unfaulted phase voltage during a ground fault on the sub-circuit. Case-specific analysis is required to determine the supplemental ground source.

The system grounding effectiveness directly affects the temporary overvoltage (TOV) and transient recovery voltage (TRV). EDTI will assess the DER impact on TOV and TRV based on available technique through interconnection studies.

6.13.1 Temporary overvoltage (TOV)

The TOV is normally referred to as a power frequency overvoltage condition lasting anywhere from about ½ cycle to several seconds in duration.

The causes of TOV include single-phase line to ground faults, ferroresonance, load rejection, loss of ground, long unloaded transmission line (due to Ferranti rise), and transformer-line inrush or the combination of these.

TOV is heavily related to system grounding characteristics. The non-effective grounding could cause unacceptable level of TOV and, subsequently, with uncontrolled TOV, equipment damage.

The DER shall not contribute to instantaneous or fundamental frequency overvoltages with the following limits:

a. The DER shall not cause the fundamental frequency line-to-ground voltage on any portion of the EEDS that is designed to operate effectively grounded, as defined by IEEE Std C62.92.1, to exceed 138% of its nominal line-to-ground fundamental frequency voltage for a duration exceeding one fundamental frequency period.

b. The DER shall not cause the line-to-line fundamental frequency voltage on any portion of the EEDS to exceed 138% of its nominal line-to-line fundamental frequency voltage for a duration exceeding one fundamental frequency period.

The DER shall not cause the instantaneous voltage on any portion of the EEDS to exceed the magnitudes and cumulative durations shown in Figure 6. The cumulative duration shall only include the sum of durations for which the instantaneous voltage exceeds the respective threshold over a one-minute time window as shown in Figure 7.

The TOV cannot be mitigated through PAIs and AAIs as described in Section 7.6.3. The TOV for both machine-based and inverter-based DERs can be mitigated by adding supplemental ground sources. TOV mitigation cost responsibility will be assessed on a case-by-case basis.

FIGURE 6

TRANSIENT AND INSTANTANEOUS OVERVOLTAGE LIMITS[21]

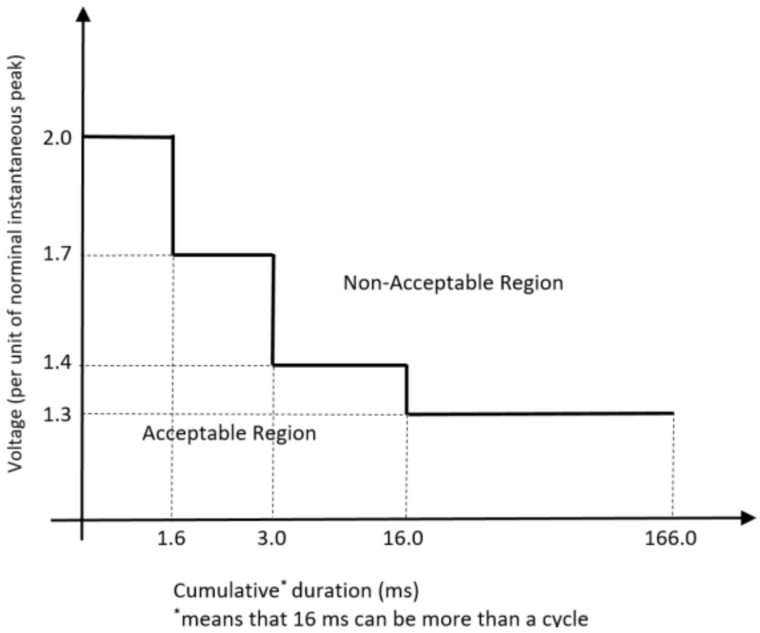
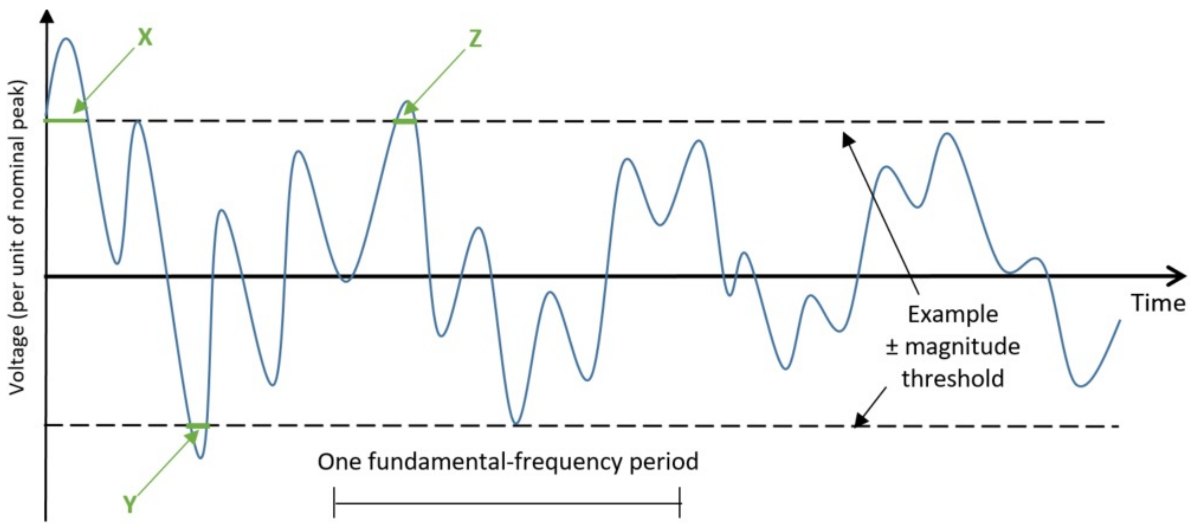


FIGURE 7

CUMULATIVE DURATION EXCEEDING MAGNITUDE THRESHOLD (SUM OF PERIOD X, Y AND Z)



[21] IEEE Std. 1547-2018, Figure 3

6.13.2 Transient recovery voltage (TRV)

According to IEEE C37.011, during the interruption process the arc voltage, which occurs across the terminals of a pole of a circuit breaker prior to current zero, approaches the normal-frequency pole-unit recovery voltage occurring after current zero, in a manner called Transient recovery voltage (TRV). If the circuit breaker is able to withstand the TRV, and also the normal frequency pole-unit recovery voltage, circuit interruption will be successful. TRV is in order of magnitude of tens of microseconds to a few milliseconds in duration.

The TRV issues associated with HV circuit breakers become a paramount issue when a DER is interconnected to the grid via a non-effectively grounded transformer. The TRV is dependent on the electrical parameters near a breaker, the loading on the circuit, and its adjacent circuits, type and size of DERs. As a result, EDTI will assess the impact of a DER on the EEDS to determine if a TRV study is required on a case-by-case basis.

7.0

Protection Requirements

The purpose of DER system interconnection protection is to reduce the risk of equipment damage and maintain the reliability of supply to customers connected to the EEDS. The protection scheme shall be designed to detect the following conditions at the PCC:

a. balanced and unbalanced system faults (e.g., line-to-ground, line-to-line, and three-phase faults);
b. frequency variations;
c. voltage variations; and
d. islanding conditions.

Depending on site-specific conditions, the protection scheme might need to detect additional conditions such as an open phase, ferroresonance, overvoltages, or excessive zero-sequence currents.

The DER system protection shall be coordinated with EDTI's circuit protection schemes and shall consider present and anticipated fault contributions.

With respect to protection functions, voltage and frequency shall be measured at the PCC or at the PoC depending on the measurement point for DER monitoring. Voltage and frequency protection will be discussed in Section 8 due to the complexity of the protection and ride-through requirements.

7.1 MINIMUM PROTECTION REQUIREMENTS

The following minimum protection functions shall be provided for an interconnected DER system operating in export mode:

a. Undervoltage (see Section 8.2.1),
b. Overvoltage (see Section 8.2.1),
c. Underfrequency (see Section 8.3.1),
d. Overfrequency (see Section 8.3.1),
e. Overcurrent (see Section 7.2),
f. Breaker Failure (see Section 7.12) and
g. Anti-Islanding (Passive, Active, DTT as applicable) (see Section 7.6).

To implement the protection requirements, various relay elements are required. The IEEE device numbers are shown in Appendix I.

7.2 PHASE AND GROUND FAULT PROTECTION

DER system protection shall be able to detect and cease energization of the distribution system in the event of:

a. a phase-to-phase fault on the interconnected distribution system circuit; and
b. a fault between phase(s) and ground on the interconnected circuit.

Directional overcurrent protection might be also required for non-export DER systems to prevent mis-operation as a result of sympathetic tripping.

7.3 OPEN-PHASE CONDITION

The DER system interconnection protection shall be capable of detecting the loss of any phase to which the DER system is connected. The loss of phase can occur within the DER system or the EEDS.

7.4 ENTERING SERVICE

When entering service, the DER shall not begin to synchronize with the EEDS unless the voltage and frequency at the measurement point are within the ranges specified in Sections 7.4.1 and 7.4.2 according to the DER technology and grade (baseline or supplemental).

7.4.1 Entering service criteria

A summary of entering service default values and ranges of adjustability is specified in Table 13 below. If for any reason the distribution system voltage and frequency shift beyond the enter service limits during the synchronization process, the DER shall stop the synchronization process and restart the enter service process once the distribution system has returned within the limits. Any proposed synchronization scheme shall be submitted to EDTI for approval prior to installation. The DER system, once synchronized, shall maintain synchronism with the EEDS unless the DER trips off for any of the mandatory criteria in this TR. The DER may cease to energize (momentary cessation) through the permissible limit areas specified in this TR. When a DER ceases to energize, it shall maintain synchronism and thus not have to re-enter service in order to continue to energize the distribution system.

TABLE 13

VOLTAGE AND FREQUENCY LIMITS[22]

Enter service criteria		Default settings, supplemental	Default settings, baseline	Range of adjustability
Voltage	Minimum value	≥ 0.917 p.u.	≥ 0.88 p.u	0.88 p.u. to 0.95 p.u.
	Maximum value	≤ 1.05 p.u.	≤ 1.10 p.u.	1.05 p.u. to 1.10 p.u.
Frequency	Minimum value	≥ 59.5 Hz	≥ 59.3 Hz	59.0 Hz to 59.9 Hz
	Maximum value	≤ 60.1 Hz	≤ 60.5 Hz	60.1 Hz to 61.0 Hz

[22] IEEE Std. 1547-2018, Figure 3

7.4.2 Performance during entering service

During the entering service stage, the DER shall be capable of the following:

a. preventing entering service when the permit service setting is disabled.

b. DER shall be capable of delaying entering service by an intentional adjustable minimum delay when the EEDS steady-state voltage and frequency are within the ranges specified in Table 13. The adjustable range of the minimum intentional delay shall be 0 s to 600 s with a default minimum delay of 300 s.

c. a DER shall increase output of active power or exchange of active power for an energy storage DER, during entering service as specified. Active power shall increase linearly, or in a stepwise linear ramp, with an average rate-of-change not exceeding the DER nameplate active power rating divided by the entering service period. The duration of the enter service period shall be adjustable over a range of 1 s to 1,000 s with a default time of 300 s. The maximum active power increase of any single step during the enter service period shall be less than or equal to 20% of the DER nameplate active power rating. Where a stepwise ramp is used, the rate of change over the period between any two consecutive steps shall not exceed the average rate-of-change over the full enter service period. This requirement is a maximum ramp rate requirement and the DER may increase output slower than specified.

7.5 SYNCHRONIZATION

7.5.1 Synchronous generators

Synchronous generators require synchronization capabilities in order to interconnect to the distribution system. The synchronization or entering service process of a synchronous generator shall:

a. ensure that the differences between the DER system and the distribution system are within the limits specified in Table 13,

b. meet the flicker requirements in Section 4.4,

c. be capable of intentionally delaying the entering service after steady-state voltage and frequency is within the ranges specified in Table 13. The adjustable range of intentional time delay shall be 0 s to 600 s with a default delay of 300 s. This time delay will restart if the voltage or frequency goes beyond the limits specified in Table 13 during the entering service period.

d. Synchronous generator DERs that produce fundamental voltage before connecting to the distribution system shall not be synchronized outside of the tolerances specified in Table 14.

TABLE 14

SYNCHRONIZATION CRITERIA FOR SYNCHRONOUS GENERATORS[23]

TOTAL DER SYSTEM CAPACITY (KVA)	FREQUENCY DIFFERENCE (ΔF, HZ)	VOLTAGE DIFFERENCE (ΔV, %)	PHASE ANGLE DIFFERENCE ($\Delta\Phi$, °)
0–500	0.3	10	20
> 500–1,500	0.2	5	15
> 1,500	0.1	3	10

7.5.2 Induction generators

The synchronization or entering service process of an induction generator shall:

a. not create a voltage change in the RMS voltage at the measurement point of greater than 3% of the nominal voltage for medium voltage connections and 5% of nominal voltage for low-voltage connection;

b. meet the flicker requirements Section 4.4;

c. not enter service unless the voltage and frequency is within the ranges specified in Table 13; and

d. be capable of intentionally delaying the enter service after steady-state voltage and frequency is within the ranges specified in Table 13. The adjustable range of intentional time delay shall be 0 s to 600 s with a default delay of 300 s. This time delay will restart if the voltage or frequency goes beyond the limits specified in Table 13 during the enter service period.

7.6 ANTI-ISLANDING PROTECTION

An electrical island is any stand-alone power system with its own generation and loads operating in balance. Islanding itself is not necessarily undesirable, but unintentional islanding can have undesirable impacts on customer and EDTI's equipment integrity. If the unintentional island is sustained for a significant period of time, personnel safety could become a concern. Even if the unintentional islanding period is short, the potential degraded power quality could still be a concern. For these reasons, the risk of unintentional islanding must be kept as low as possible through anti-islanding protection

Anti-islanding protection is required to:

a. prevent power quality problems to other customers connected to the island;

b. prevent out-of-phase paralleling between the distribution system and the DER system; and

c. reduce the risk of safety hazards.

[23] CSA C22.3 No.9:20, Table 18

Unless approved in writing by EDTI, a DER facility shall not island with a portion of the EEDS. The level of the anti-islanding protection required depends on how a DER system is interconnected. Sections 7.6.1 through 7.6.3 specifies anti-islanding protection requirements. For an unintentional island in which the DER energizes a portion of the distribution system through the PCC, the DER shall detect the island, cease to energize the distribution system, and trip within 2 s of the formation of an island.

EDTI will review and approve alternative protection schemes on a case-by-case basis.

7.6.1 Passive anti-islanding (PAI) protection

The PAI protection in a DER control monitors various parameters of the DER's terminal voltage, and trip the DER if the selected parameter exceeds some threshold. What defines the protection as passive is that the DER control does not actively try to change the value of the parameter being monitored; it simply monitors, processes and reacts. Some parameters that have been used in the PAI protection include the following:

- Over/undervoltage and over/underfrequency
- Voltage phase (the phase is monitored for a sudden jump)
- Voltage or current harmonic distortion
- Rate of change of frequency
- Rate of change of real power
- Rate of change of voltage vector
- Various harmonic pattern recognition methods, using FFTs, wavelets, Kalman filters, or other spectral techniques

In general, the PAI protection has great difficulty eliminating all non-detection zones (NDZ) because it is difficult to find thresholds or patterns that are totally unique to islanding, and do not occur under normal operating conditions. Thus, the PAI protection usually involve a trade-off between the extent of the NDZ and the rate of occurrence of nuisance trips. The behaviour and performance of passive methods is difficult to predict when multiple inverters are present in the potential island.

7.6.2 Active anti-islanding (AAI) protection

The active anti-islanding (AAI) protection intentionally creates and introduces perturbations into the system parameters, such as voltage, frequency and harmonics. These perturbations are designed to have negligible impact during grid connected operation while significantly disturb the potential stable operation of DERs in the islanded grid. The AAI protection is generally more successful in loss of grid detection than passive methods because they tend to destabilize the potential island by making the generation-load balance more difficult to achieve. The main AAI protection methods include the following:

- Impedance detection. In impedance detection, the DER control periodically perturbs its output current and checks to see whether there is a corresponding change in voltage, thereby measuring the source impedance as seen from the DER control. If the detected impedance is too high, the DER trips.

- Positive feedback based methods, such as the Sandia Frequency Shift (SFS), Sandia Voltage Shift (SVS), Slip Mode Frequency Shift (SMS), Active Frequency Shift (AFS), Current Magnitude Variation (CMV), etc. In these methods, the DER control employs positive feedback on voltage or frequency. If the inverter detects a change in one of these parameters, it attempts to "push" on that parameter in the same direction, trying to drive it out of bounds. If it can, the DER trips.
- Impedance detection plus positive feedback. Most commercial DER controls, especially, inverters use some variant of this technique, in which the benefits of positive feedback are combined with the benefits of impedance detection. This method has been vetted in simulation, laboratory tests, and field deployments.

The AAI protection is more effective than the PAI protection and can eliminate the NDZ. However, there are many different AAI algorithms which cause DERs with different AAI algorithms to interact. The interaction can slow frequency change, require longer detection time and make it more difficult to detect the island. In addition, the new voltage and frequency ride-through requirements specified by CSA C22.3 No.9:20 expand the NDZ.

7.6.3 Direct transfer trip (DTT)

As discussed in Sections 7.6.1 and 7.6.2, the PAI and AAI protections can detect islands but they may have NDZ or longer detection time due to the mixed AAIs from different inverter manufacturers and PAIs from different relays for machine-based DERs. As a result, EDTI requires direct transfer trips (DTTs) for DERs with ratings higher than the threshold described below.

On the EEDS, the minimum load on a given 15 kV or 25 kV circuit is about 2,000 kVA. If a DER with 1,000 kW rating is connected to a circuit without a DTT, it is possible for the DER and the customers on the circuit to form an "island" when the circuit breaker is open after a fault. Therefore, all DERs (machine-based DERs have PAI protection in most cases and inverter-based DERs have AAI protection) rated 1,000 kW or larger with the ability to export power onto the EEDS shall be equipped with DTT protection.

The DTT protection can ensure that DERs do not island in the event of a circuit breaker or intermediate automatic circuit recloser opening. The requirements for the DTT design are as follows:

- A DER end-open signal must be sent to the breaker relay of the circuit that the DER is connected to make sure the breaker is safe to reclose after tripping on a fault.
- The DER lockout or lockout of the main breaker (for DER facilities that want to operate in isolation) must occur at the point of common coupling location within 3 s of the circuit breaker or the automatic circuit recloser opening.
- Fail-safe lockout must occur within 6 s of communication loss.
- The power producer is responsible for detecting and tripping in the event of communication loss.

If transfer trip protection is installed for a DER, the DER must operate on the specified circuit. When the DER is transferred to another circuit from the specified circuit, the DER must be turned off.

The DTT requirement can be waived if a power producer can demonstrate the DER will be tripped off within 2 s when a circuit breaker or an immediate recloser is open through a study using a commercial transient analysis program.

EDTI reserves the right to require DTT protection for any DER regardless the size. As a result, DERs of less than 1,000 kW should have provision for the capability to receive EDTI trip signals and cease generation; i.e., they should have provision for the DTT installation. The actual implementation is not required when the DER is commissioned but may be requested by EDTI at a later date to be implemented at the power producer’s cost.

A DTT is not required if a DER is an induction generator that cannot be self-excited, regardless of the rating of the DER.

7.7 DESENSITIZATION OF PROTECTION DEVICES

Desensitization of protection devices is a phenomenon from which the contribution of fault current from substation and DERs will decrease as the capacity of DER increases. As a result, the protection relays at the substation and DERs may take longer, or in some cases be unable to detect and clear the faults due to decreased levels of fault current contributions from each source. This reduces sensitivity and reliability of protection. To maintain the reliability of the protection system on the EEDS, it is required that each DER shall not reduce the fault current level without any DERs by 5% and the total fault current level reduction cannot exceed 10% at any point on a circuit. EDTI will evaluate the fault current reduction during the DER interconnection study stage.

7.8 INTENTIONAL ISLANDING

A DER system that has the ability to operate as an intentional island shall be designed and operated in coordination with protection on the EEDS. There are two means by which an intentional island system can transition to an islanded condition: unscheduled and scheduled.

Unscheduled intentional islands

Unscheduled intentional islands are formed autonomously from local detection of abnormal conditions at the interface(s) with the EEDS, and then automatic relay action that triggers switching action to isolate the intentional island rapidly from the EEDS.

Scheduled intentional islands

Scheduled intentional islands are formed through DER operator or EDTI manual action or other operating dispatch means that trigger the transition from being in parallel and synchronized with the EEDS to operation as an islanded system. Reasons for forming a scheduled intentional island can include economic and enhanced reliability.

Intentional islanding is only permitted under the written approval of EDTI. When operating in an intentional island, participating DERs might have to adjust several control and protection settings. These alternate settings and ranges of adjustability shall be enabled only when the intentional island is isolated from the EEDS. In order to meet this requirement, adaptive protection and control settings might be required.

7.9 ELECTROMAGNETIC INTERFERENCE (EMI)

The protection, control, and communication functions of the interconnection system shall not fail, operate improperly, or provide misinformation as a result of EMI and shall comply with the following, where applicable:

a. CAN/CSA-CEI/IEC 61000-4-3, using Level X, 35 V/m, in accordance with IEEE C37.90.2; or

b. IEEE C37.90.2.

The power producer shall provide documentation of compliance with Item a) or b).

7.10 SURGE WITHSTAND

The protection, control, and communication functions of the interconnection system shall not fail, operate improperly, or provide misinformation as a result of voltage of current surges and shall comply with the following, where applicable:

a. 100 kHz ring wave (6 kV, 500 A, 12 Ω) with at least 10 wave applications, each separated by at least 10 s, in accordance with the following:
   i. ANSI/IEEE C62.45, Category B; or
   ii. CAN/CSA-CEI/IEC 61000-4-12, Level X, 6 kV.

b. 1.2/50 μs – 8/20 μs combination wave (6 kV, 3 kA, 2 W) with at least 10 wave applications, each separated by at least 30 s, in accordance with the following:
   i. ANSI/IEEE C62.45, Category B; or
   ii. CAN/CSA-IEC 61000-4-5, Level X, 6 kV.

c. Electrostatic discharge (2, 4, and 8 kV) in accordance with the following:
   i. IEEE C37.90.3; or
   ii. CAN/CSA-CEI/IEC 61000-4-2, Levels 1, 2, and 4.

d. 5/50 ns electrical fast transient, burst at 4 kV, in accordance with the following:
   i. IEEE C37.90.1;
   ii. ANSI/IEEE C62.45, Category B; or
   iii. CAN/CSA-CEI/IEC 61000-4-4, Level 4; and

e. 1 MHz damped oscillatory wave, burst at 2.5 kV, in accordance with the following:
   i. IEEE C37.90.1; or
   ii. CAN/CSA-CEI/IEC 61000-4-12, Level X, 2.5 kV.

Equipment rated greater than 1,000 V shall be tested in accordance with applicable standards.

7.11 BATTERIES AND AUXILIARIES

Batteries and auxiliaries, where provided, shall have adequate capacity and rating to ensure the operation of all protection functions when the principal source of power fails. Protection functions shall remain operational for 1,000 s specified in Table 20 following disturbances on EEDS or loss of supply from the EEDS. This can be achieved using batteries and a charger connected to the main supply or by using an uninterruptible power supply with sufficient capacity. Capacitors (i.e., capacitor trip) shall not be used for this purpose.

7.12 PROTECTION SCHEME FAILURE

If, on a DER site, the interconnection protection system or breaker trip coils fail, or if auxiliary supply is lost, the DER system shall cease energization of the EEDS without delay.

If the transfer trip communication function fails, the DER system shall cease to energize the EEDS within 2 s.

The power producer shall provide evidence to EDTI that protection scheme failure can be mitigated using self-diagnostic features, redundancy, or fail-safe design.

Protection functions shall remain operational for at least 1,000 s specified in Table 20.

All breaker failure schemes shall be submitted to EDTI for review and approval in order to be implemented.

7.13 INSTRUMENT TRANSFORMERS USED FOR PROTECTION

Instrument transformers used for protection shall meet the requirements of CAN/CSA-C60044-6 or IEEE C57.13.

8.0

Response to Abnormal Conditions on EDTI System

8.1 GENERAL

Abnormal frequency and voltage conditions can arise on EDTI's distribution or transmission system to which the DER shall appropriately respond. DER response shall coordinate with EDTI's performance requirements. All performance requirements in this Section shall be met at the measurement point identified in Section 6.3 and according to accuracy level identified in Section 6.2.

8.2 VOLTAGE PROTECTION AND RIDE-THROUGH

8.2.1 Mandatary voltage tripping requirements

The DER system shall be equipped with overvoltage and undervoltage protection that shall:

a. cease to energize and trip within the clearing times for undervoltage and overvoltage limits in accordance with Table 15 (also see Figure 8) for baseline grade DERs and Table 16 (also see Figure 9) for supplemental grade DERs;

b. have adjustable voltage and clearing time set points. EDTI may specify other voltage and clearing time trip settings within the range of adjustability to fulfill other considerations; and

c. have a measurement location at the PCC to provide with an additional adjustable overvoltage element to enforce compliance with CSA C235 at the PCC. The pickup shall be adjustable between 106% and 110% and the time shall be adjustable between 45 s to 120 s.

TABLE 15

TRIP REQUIREMENTS FOR VOLTAGE PROTECTION - BASELINE GRADE[24]

TRIP FUNCTION	RECOMMENDED SETTINGS		RANGES OF ADJUSTABILITY	
	VOLTAGE (% OF NOMINAL VOLTAGE)	CLEARING TIME (S)	VOLTAGE (% OF NOMINAL VOLTAGE)	CLEARING TIME (S)
0V3	120	0.16	N/A	N/A
0V2	110	2.0	110 - 120	1.0 - 13.0
0V1	106	60.0	106 - 110	30 - 90
UV1	88	**2.0**	0 - 88	2.0 - 21.0
UV2	45	0.16	0 - 50	0.16 - 2.0

[24] CSA C22.3 No.9:20, Table 10 with modification

TABLE 16

TRIP REQUIREMENTS FOR VOLTAGE PROTECTION - SUPPLEMENTAL GRADE[25]

TRIP FUNCTION	RECOMMENDED SETTINGS		RANGES OF ADJUSTABILITY	
	VOLTAGE (% OF NOMINAL VOLTAGE)	CLEARING TIME (S)	VOLTAGE (% OF NOMINAL VOLTAGE)	CLEARING TIME (S)
0V3	120	0.16	N/A	N/A
0V2	110	2.0	110 - 120	1.0 - 13.0
0V1	106	60.0	106 - 110	30 - 90
UV1	88	**10.0**	0 - 88	2.0 - 21.0
UV2	45	0.16	0 - 50	0.16 - 2.0

8.2.2 Voltage disturbance ride-through requirements

8.2.2.1 General requirements

In the event of temporary voltage disturbance, the DER system shall:

a. operate and maintain synchronism during voltage ride-through as specified in Table 17 (also see Figure 8) for baseline grade DERs and Table 18 (also see Figure 9) for supplemental grade DERs. The voltage disturbance ride-through requirements specified in this section do not apply when frequency is outside of the ride-through range specified Table 17, and

b. be designed to provide the voltage disturbance ride-through capability specified in this section. Any tripping of the DER, or other failure to provide the specified ride-through capability, due to DER self-protection as a direct or indirect result of a voltage disturbance within a ride-through region, shall constitute non-compliance with this TR.

[25] CSA C22.3 No.9:20, Table 11 with modification

FIGURE 8

VOLTAGE RIDE-THROUGH REQUIREMENTS — BASELINE GRADES[26]

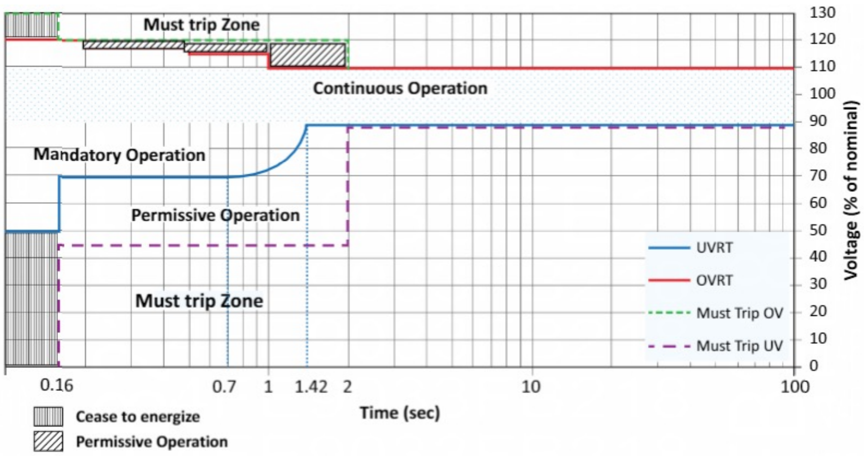


TABLE 17

VOLTAGE RIDE-THROUGH – BASELINE GRADE[27]

VOLTAGE RANGE (% OF NOMINAL VOLTAGE)	MINIMUM RIDE-THROUGH TIME (S) (DESIGN CRITERIA)	MAXIMUM RESPONSE TIME (S) (DESIGN CRITERIA)	RESPONSE
V > 120	N/A[28]	0.16	Cease to energize
117.5 < V ≤ 120	0.2	N/A	Mandatory operation
115 < V ≤ 117.5	0.5	N/A	Mandatory operation
110 V ≤ 115	1	N/A	Mandatory operation
88 ≤ V ≤ 110	Infinite	N/A	Continuous operation
70 ≤ V < 88	Linear slope of 4 s/1p.u. voltage starting at 0.7 s @ 0.7 p.u.: $T_{VTR} = 0.7s + \frac{4s}{1p.u.}$ (v - 0.7 p.u.)	N/A	Mandatory operation
50 ≤ V < 70	0.16	N/A	Mandatory operation
V < 50	N/A[28]	0.16	Cease to energize

[26] CSA C22.3 No.9:20, Figure 6
[27] CSA C22.3 No.9:20, Table 12
[28] Cessation of current of DER in not more than the maximum specified time and with no intentional delay. This does not necessarily imply disconnection, isolation, or trip of the DER

FIGURE 9

VOLTAGE RIDE-THROUGH REQUIREMENTS – SUPPLEMENTAL GRADES[29]

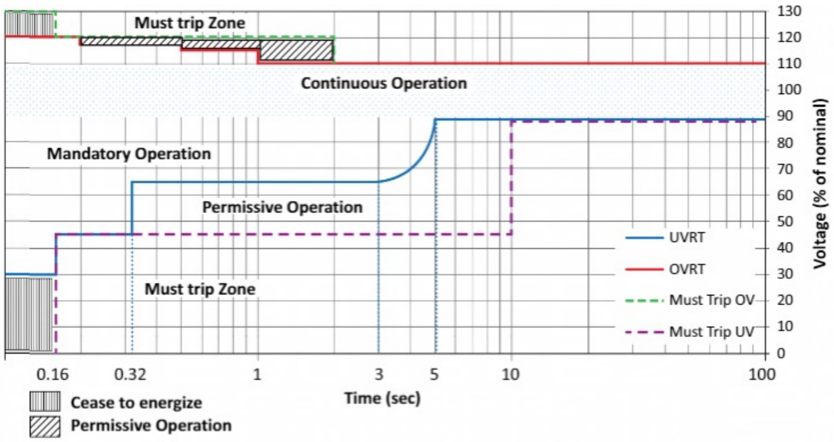


TABLE 18

VOLTAGE RIDE-THROUGH – SUPPLEMENTAL GRADE[30]

VOLTAGE RANGE (% OF NOMINAL VOLTAGE)	MINIMUM RIDE-THROUGH TIME (S) (DESIGN CRITERIA)	MAXIMUM RESPONSE TIME (S) (DESIGN CRITERIA)	RESPONSE
V > 120	N/A[28]	0.16	Cease to energize
117.5 < V ≤ 120	0.2	N/A	Mandatory operation
115 < V ≤ 117.5	0.5	N/A	Mandatory operation
110 V ≤ 115	1	N/A	Mandatory operation
88 ≤ V ≤ 110	Infinite	N/A	Continuous operation
65 ≤ V < 88	Linear slope of 8.7 s/1p.u. voltage starting at 3 s @ 0.65 p.u.: $T_{VTR} = 3s + \frac{8.7s}{1p.u.}(v - 0.65\ p.u.)$	N/A	Mandatory operation
45 ≤ V < 65	0.32	N/A	Mandatory operation
30 ≤ V < 45	0.16	0.16	Cease to energize
V < 30	N/A[28]	0.16	Cease to energize

[28] Cessation of current of DER in not more than the maximum specified time and with no intentional delay. This does not necessarily imply disconnection, isolation, or trip of the DER

[29] CSA C22.3 No.9:20, Figure 7

[30] CSA C22.3 No.9:20, Table 12

8.2.2.2 Voltage disturbances within continuous operation region

Voltage disturbances of any duration, for which the applicable voltage as specified in Section 6.5 remains within the extreme operating range as defined by CSA C235:19, shall not cause the DER to cease to energize and trip from the EEDS. The DER shall remain in operation during any such disturbance, and shall continue to deliver available active power of magnitude at least as great as its pre-disturbance level of active power, prorated by the per-unit voltage level of the least phase voltage if that voltage is less than the nominal voltage. Temporary deviations of active power having durations not exceeding 0.5 s shall be allowed.

Exception: Three-phase DER may cease to energize and trip if the negative sequence component of the applicable voltage is greater than 5% of the nominal voltage for greater than 60 s or greater than 3% of the nominal voltage for greater than 300 s, provided that the voltage imbalance is neither caused nor aggravated by unbalanced currents of the local load.

8.2.2.3 Low-voltage ride-through

For low-voltage ride-through, the relevant voltage at any given time shall be the least magnitude of the individual applicable phase-to-neutral, phase-to-ground, or phase-to-phase voltage relative to the corresponding nominal system voltage as specified in Section 6.5.

8.2.2.3.1 Low-voltage ride-through capability

During temporary voltage disturbances, for which the applicable voltage on the phase that has the least voltage magnitude is less than the minimum of the continuous operation region, and within the corresponding voltage ranges and cumulative duration (minimum time) specified in Table 17 for base grade and Table 18 for supplemental grade, the DER shall be capable to ride-through and shall:

- maintain synchronism with the EEDS;
- not trip; and
- restore output as specified in Section 8.2.2.7.

8.2.2.3.2 Low-voltage ride-through performance

During low-voltage ride-through, the DER shall operate in the following operating modes as specified in Table 17 for base grade and Table 18 for supplemental grade with the following requirements.

During temporary voltage disturbances, for which the applicable voltage on the phase that has the least voltage magnitude is within the mandatory operation region, the DER shall:

- maintain synchronism with the EEDS.
- continue to exchange current with the EEDS.
- neither cease to energize nor trip.

A DER of supplemental grade shall, by default, not reduce its total apparent current during the disturbance period in mandatory operation mode below 80% of the pre-disturbance value or of the corresponding active current level subject to the available active power, whichever is less, subject to the following:

- Active and reactive current oscillations that are positively damped are permitted during the disturbance and post-disturbance period.
- Transient apparent current magnitude changes having duration less than 30 ms, and dynamic current magnitude oscillations for which the mean value is greater than or equal to the pre-disturbance value constitute exceptions to this requirement.

8.2.2.4 High-voltage ride-through

For high-voltage ride-through, the relevant voltage at any given time shall be the greatest magnitude of the individual applicable phase-to-neutral, phase-to-ground or phase-to-phase voltage relative to the corresponding nominal system voltage as specified in Section 6.5.

8.2.2.4.1 High-voltage ride-through capability

During temporary voltage disturbances, for which the applicable voltage on the phase having the greatest voltage magnitude is greater than the maximum of the continuous operation region, and within the corresponding voltage ranges and cumulative duration (minimum time) specified in Table 17 for abnormal operating performance baseline grade Table 18 for supplemental grade, the DER shall be capable to ride-through and shall:

- maintain synchronism with the EEDS;
- not trip; and
- restore output as specified in Section 8.2.2.7.

8.2.2.4.2 High-voltage ride-through performance

During high-voltage ride-through, the DER shall operate in the following operating modes as specified in Table 17 for abnormal operating performance baseline grade, Table 18 for supplemental grade with the following requirements:

During temporary voltage disturbances, for which the applicable voltage on the phase having the greatest voltage magnitude is within the permissive operating region, the DER:

- shall maintain synchronism with the EEDS or shall not trip.
- may continue to exchange current with the EEDS or may cease to energize.
- if DER ceases to energize, shall restore output as specified in Section 8.2.2.7.

8.2.2.5 Ride-through of consecutive voltage disturbances

The requirements for continued operation (ride-through), or restore output shall apply to multiple consecutive voltage disturbances within a ride-through operating region, for which the voltage range and corresponding cumulative durations are specified in Table 15 for abnormal operating performance base grade, Table 16 for supplemental grade. These requirements are subject to the following provisions that specify conditions in Table 19 for which a DER may trip:

a. For a set of consecutive disturbances in which voltages fall within a ride-through operating region multiple times, each interspersed by a period of voltage within the continuous operation region that has a duration no greater than specified in Table 19 Column 3 for the respective performance category, the cumulative duration of voltage within the respective ride-through operating region for all such disturbances shall be compared with the maximum required duration for the respective voltage disturbance severity. If this cumulative duration exceeds the required duration, the DER may trip.

b. If voltages remain entirely within the continuous operation region for a time period greater than specified in Table 19, Column 3 for the respective performance category, any further disturbance shall be considered as a new set of disturbances, and a new accumulation of ride-through duration as defined in item a) shall apply.

c. The DER shall not be required to ride through any more ride-through disturbance sets than the maximum number given in Table 19, Column 2 within the time period specified in Table 17, Column 4. Once a period-of-time as given in Table 19, Column 4 has passed since the last disturbance, the DER shall be required to ride through any new sets of disturbances as specified in item a) and item b).

Exception: DER shall be allowed to trip if the timing of multiple consecutive voltage disturbances during a specific event stimulate electromechanical oscillations to the degree where DER synchronism is lost or potential damage to the DER may occur.

TABLE 19

VOLTAGE RIDE-THROUGH FOR CONSECUTIVE TEMPORARY VOLTAGE DISTURBANCES CAUSED BY UNSUCCESSFUL RECLOSING FOR DER OF ABNORMAL OPERATING PERFORMANCE BASE AND SUPPLEMENTAL GRADES[31]

COL.1	COL.2`	COL.3	COL.4
Grade	Maximum number of ride-through disturbance sets	Minimum time between successive disturbance sets (s)	Time window for new count of disturbance sets (min)
Base	2	20.0	60
Supplemental	2	10.0	60

[31] IEEE Std. 1547-2018, Table 17

8.2.2.6 Dynamic voltage support

Dynamic voltage support from a DER can support the applicable voltage by supplying the EEDS with a current during low-voltage ride-through and high-voltage ride-through operation. Alternate means of DER control and designs can exist to provide dynamic voltage support. Support of the applicable voltage can provide benefits to the EEDS and BPS.

8.2.2.6.1 Dynamic voltage support capability

Any DER may have the capability of dynamic voltage support during low-voltage ride-through and high voltage ride-through.

8.2.2.6.2 Dynamic voltage support performance

The dynamic voltage support capability may be utilized during mandatory operation or permissive operation under a mutual agreement with the EEDS operator considering both the capability and the DER-specific implementation of the dynamic voltage support function. The DER shall maintain synchronism with the EEDS and may provide dynamic voltage support to the EEDS during and following temporary voltage disturbances, for which the applicable voltage on any phase is as follows:

a. less than the minimum of the continuous operation region and within either the mandatory operation or the permissive operation region, or

b. greater than the maximum of the continuous operation region and within the permissive operation region.

The dynamic voltage support shall not cause the DER to cease to energize in situations where the DER would not cease to energize without the dynamic voltage support.

8.2.2.7 Restore output with voltage ride-through

8.2.2.7.1 Restore output without dynamic voltage support

If the DER rides through a voltage disturbance without trip and the DER does not provide dynamic voltage support (see Section 8.2.2.6) while in a mandatory operation or permissive operation region, once the applicable voltage surpasses the lower value of the mandatory operation region during low-voltage ride-through or the applicable voltage returns below the upper value of the continuous operation region during high-voltage ride-through, the DER shall:

- maintain synchronism with the EEDS.
- restore output of active current to at least 80% of pre-disturbance active current level within 0.4 s. Active and reactive current oscillations in the post-disturbance period that are positively damped are acceptable.

8.2.2.7.2 Restore output with dynamic voltage support

If the DER rides through a voltage disturbance without trip and the DER provides dynamic voltage support while in a mandatory operation or permissive operation region, once the applicable voltage enters the continuous operation region, the DER shall:

- maintain synchronism with the EEDS.
- continue to provide dynamic voltage support up to 5 s after the applicable voltage surpasses the lower value of the continuous operation region and restore output of active current to at least 80% of pre-disturbance active current level or to the available active current subject to reactive current priority, whichever is less, within 0.4 s.
- discontinue providing dynamic voltage support 5 s after the applicable voltage surpasses the lower value of the continuous operation region and resume reactive power functionality for normal conditions as defined in Section 6.10 for the mode that has been selected.

8.3 FREQUENCY PROTECTION AND RIDE-THROUGH

8.3.1 Mandatory frequency tripping requirements

When the system frequency is above OF2 or below UF2 given in Table 20, and the fundamental-frequency component of voltage on any phase is greater than 30% of nominal, the DER shall cease to energize the EEDS and trip within 0.16 s. Underfreqency and overfrequency tripping thresholds and clearing times shall be adjustable over the ranges of allowable settings specified in Table 20. The recommended underfrequency and overfrequency trip settings are shown in Table 20.

Two overfrequency trip functions, OF1 and OF2, and two underfrequency trip functions, UF1 and UF2 apply simultaneously. For the overfrequency (OF) and underfrequency (UF) trip functions clearing time ranges and for the OF trip functions frequency ranges, the lower value is a limiting requirement (the setting shall not be set to lower values) and the upper value is a minimum requirement (the setting may be set above this value). For the UF trip functions frequency ranges, the upper value is a limiting requirement (the setting shall not be set to greater values) and the lower value is a minimum requirement (the setting may be set to lower values).

TABLE 20

TRIP REQUIREMENTS FOR FREQUENCY PROTECTION – BASELINE AND SUPPLEMENTAL GRADES[32]

(See Sections 7.4.5, 7.8, 7.9, 8.2.4.7 and IEEE Std. 1547-2018)

TRIP FUNCTION	RECOMMENDED SETTINGS		RANGES OF ADJUSTABILITY	
	FREQUENCY (HZ)	CLEARING TIME (S)	FREQUENCY (HZ)	CLEARING TIME (S)
OF2	62.0	0.16	61.8 – 66.0	0.16 – 1,000.0
OF1	61.2	300.0	61.0 – 66.0	180.0 – 1,000.0
UF1	58.5	300.0	50.0 – 59.0	180.0 – 1,000.0
UF2	56.5	0.16	50.0 – 57.0	0.16 – 1,000.0

8.3.2 Frequency disturbance ride-through requirements

DER shall meet one of the abnormal operating performance grades, baseline grade or supplemental grade of this TR. The frequency disturbance ride-through requirements specified in this section do not apply when voltage is outside of the ride-through range specified in Section 8.2.2.

DER shall be designed to provide the frequency disturbance ride-through capability specified in this section without exceeding DER capabilities. Any tripping of the DER, or other failure to provide the specified ride-through capability, due to DER self-protection as a direct or indirect result of a frequency disturbance within a ride-through region, shall constitute non-compliance with this TR.

The power producer shall specify its abnormal operating performance grade within the nameplate information according to this TR.

For frequency disturbances outside the ride-through operating region parameters (frequency range and corresponding cumulative duration, minimum time) specified in Table 21 for baseline and supplemental grades, requirements for continued operation (ride-through), or restore output subsequent to the frequency disturbance, shall not apply.

[32] CSA C22.3 No.9:20, Table 9

TABLE 21
FREQUENCY RIDE-THROUGH – BASELINE AND SUPPLEMENTAL GRADES[33]

FREQUENCY RANGE (HZ)	MINIMUM RIDE-THROUGH TIME (S) (DESIGN CRITERIA)
$f > 62.0$	No ride-through requirements apply to this range
$61.2 < f \leq 62$	299
$58.8 \leq f \leq 61.2$	Infinite*
$57.0 \leq f < 58.8$	299
$f < 57.0$	No ride-through requirements apply to this range

* Applicable only for a per-unit ratio of voltage/frequency of V/f ≤1.1.

8.3.2.1 Frequency disturbances within continuous operation region

Frequency disturbances of any duration, for which the system frequency remains between 58.8 Hz and 61.2 Hz and the per-unit ratio of Voltage/frequency is less than or equal to 1.1, shall not cause the DER to trip. The DER shall remain in operation during any such disturbance, and shall be able to continue to exchange active power at least as great as its pre-disturbance level of power.

8.3.2.2 Low-frequency ride-through

8.3.2.2.1 Low-frequency ride-through capability

During temporary frequency disturbances, for which the system frequency is less than 58.8 Hz and greater than or equal to 57.0 Hz, and having a cumulative duration below 58.8 Hz of less than 299 s in any ten minute period, the DER shall be capable to ride-through and shall:

- maintain synchronism with the EEDS.
- not reduce its active power output below the value specified in Table 22, depending on the DER performance grade as described in Section 5.4. Reductions of available active power due to the underfrequency event shall not be allowed when the voltage is within the continuous operating range. Active power may be reduced in proportion with the grid voltage when the grid voltage is below the level for continuous operation.

[33] CSA C22.3 No.9:20, Table 14

TABLE 22

FREQUENCY RIDE-THROUGH REQUIREMENTS FOR ACTIVE POWER OUTPUT CAPABILITY FOR ABNORMAL OPERATING PERFORMANCE BASELINE AND SUPPLEMENTAL GRADES[34]

GRADE	ACTIVE POWER OUTPUT CAPABILITY
Baseline	80% of nameplate active power rating or the pre-disturbance active power output whichever is less
Supplemental	Pre-disturbance active power output

8.3.2.2.2 Low-frequency ride-through performance

During low-frequency ride-through, the DER shall operate in the mandatory operation region as specified in Table 21 for abnormal operating performance baseline and supplemental grades with the following requirements:

During temporary frequency disturbances, for which the system frequency is within the mandatory operation region, the DER shall:

- maintain synchronism with the EEDS.
- continue to exchange pre-disturbance current with the EEDS subject to limitations specified in Table 22 and shall neither cease to energize nor trip. Active and reactive current oscillations that are positively damped are acceptable.
- modulate active power to mitigate the underfrequency conditions depending on the DER performance grade as described in Section 6.11.3[35]. Neither provision of energy storage capability, nor operation of DER at power outputs less than the power available in order to allow reserve for power increase in response to underfrequency (pre-curtailment), are requirements of this TR.

8.3.2.3 High-frequency ride-through

8.3.2.3.1 High-frequency ride-through capability

During temporary frequency disturbances, for which the system frequency is greater than 61.2 Hz and less than or equal to 61.8 Hz, and having a cumulative duration greater than 61.2 Hz of less than 299 s in any ten-minute period, the DER shall be capable to ride-through and shall maintain synchronism with the EEDS.

[34] IEEE Std. 1547-2018, Table 20
[35] Frequency droop will be required in the future by coordinating with AESO.

8.3.2.3.2 High-frequency ride-through performance

During high-frequency ride-through, the DER shall operate in mandatory operation region as specified in Table 22 for abnormal operating performance grade baseline and supplemental with the following requirements:

During temporary frequency disturbances, for which the system frequency is within the mandatory operation region, the DER shall:

- maintain synchronism with the EEDS.
- continue to exchange current with the EEDS and shall neither cease to energize nor trip.
- modulate active power to mitigate the overfrequency conditions.

8.3.2.4 Rate of change of frequency (ROCOF) ride-through

Within the continuous operation region and the low-frequency and high-frequency ride-through operating regions (frequency range and corresponding cumulative duration, minimum time), the DER shall ride through and shall not trip for frequency excursions having magnitudes of rates of change of frequency (ROCOF) that are less than or equal to the values specified in Table 23 per abnormal operating performance grade. As specified in Section 6.5, the ROCOF shall be the average rate of change of frequency over an averaging window of at least 0.1 s.

TABLE 23

RATE OF CHANGE OF FREQUENCY (ROCOF) RIDE-THROUGH REQUIREMENTS FOR DER OF ABNORMAL OPERATING PERFORMANCE GRADES[36]

BASELINE	SUPPLEMENTAL
0.5 Hz/s	2.0 Hz/s

[36] IEEE Std. 1547-2018, Table 21

9.0

Interoperability, Information Exchange, Information Models, and Protocols

9.1 INTEROPERABILITY REQUIREMENTS

A DER shall have provisions for a local DER interface capable of communicating (local DER communication interface) to support the information exchange requirements specified by IEEE Std. 1547-2018 for all applicable functions that are supported in the DERs.

Emergency and standby DERs are exempt from the interoperability requirements.

9.2 MONITORING, CONTROL, AND INFORMATION EXCHANGE REQUIREMENTS

The specific DER functionality required by this Technical Requirement results in the set of mandatory information elements identified in Sections 9.2.1 through 9.2.4. These information elements shall be supported by the DERs as indicated to support the associated DER functionality.

For information interoperability, these communication capabilities shall use a unified information model, and non-proprietary protocol encodings based on international standards or open industry specifications as described in Section 9.3.

The information to be exchanged falls into the following four categories:

- Nameplate information: This information is indicative of the as-built characteristics of the DERs. This information may be read.
- Configuration information: This information is indicative of the present capacity and ability of the DERs to perform functions. This information may be read or written.
- Monitoring information: This information is indicative of the present operating conditions of the DERs. This information may be read.
- Management information: This information is used to update functional and mode settings for the DERs. This information may be read or written.

A full list of information exchange requirements can be found in Appendix II.

9.2.1 Monitoring information

The DER shall be capable of providing monitoring information through a local DER communication interface at the reference point of applicability and shall include at a minimum the information contained in Table 24. The information shall be the latest value that has been measured within the required response time, ≤ 30 s.

TABLE 24
MONITORING INFORMATION[37]

PARAMETER	DESCRIPTION
Active power	Active power in watts
Reactive power	Reactive power in vars
Voltage	Voltage(s) in volts (one parameter for single-phase and three parameters for three-phase systems)
Frequency	Frequency in Hertz
Operational state	Operational state of the DER. The operational state should represent the current state of the DER. The minimum supported states are on and off but additional states may also be supported.
Connection status	Power-connected status of the DER
Alarm status	Active alarm status
Operational state of charge	0% to 100% of operational energy storage capacity

[37] IEEE Std. 1547-2018, Table 29

9.2.2 Nameplate information

Nameplate information shall be available through a local DER communication interface and include at a minimum the information contained in Table 25.

TABLE 25
NAMEPLATE INFORMATION[38]

PARAMETER	DESCRIPTION
Active power rating at unity power factor (nameplate active power rating)	Active power rating in watts at unity power factor
Active power rating at specified sourcing power factor	Active power rating in watts at specified sourcing power factor
Specified sourcing power factor	Sourcing power factor as described in 6.10.1
Active power rating at specified consuming power factor	Active power rating in watts at specified consuming power factor
Specified consuming power factor	Consuming power factor as described in 6.10.1
Apparent power maximum rating	Maximum apparent power rating in voltamperes
Grades of DER	Indication of reactive power and voltage/power control capability and voltage/frequency ride-through capability. (baseline/supplemental as described in 5.4)
Reactive power absorbed maximum rating	Maximum absorbed reactive power rating in vars
Reactive power injected maximum rating	Maximum injected reactive power rating in vars
Active power charge maximum rating	Maximum active power charge rating in watts
Apparent power charge maximum rating	Maximum apparent power charge rating in voltamperes. May differ from the apparent power maximum rating.
AC voltage nominal rating	Nominal AC voltage rating in RMS volts
AC voltage maximum rating	Maximum AC voltage rating in RMS volts
AC voltage minimum rating	Minimum AC voltage rating in RMS volts
Supported control mode functions	Indication of support for each control mode function
Reactive susceptance that remains connected to the EEDS in the cease to energize and trip state	Reactive susceptance that remains connected to the EEDS in the cease to energize and trip state
Make, model, serial number and version	Manufacturer, model, serial number and version

[38] IEEE Std. 1547-2018, Table 28

9.2.3 Configuration information

Configuration information shall be available through a local DER communication interface to allow the setting and reading of the currently active values.

Each rating in Table 25 may have an associated configuration setting that represents the as-configured value. If a configuration setting value is different from the corresponding nameplate value, the configuration setting value shall be used as the rating within the DER. Changes to the configuration setting shall be made with mutual written agreement between the power producer and EDTI Operator.

Configuration settings are intended to be used as a configuration option as nameplate alternatives. Configuration settings are not intended for continuous dynamic adjustment.

9.2.4 Management information

Management information is used to update functional and mode settings for the DERs. This information may be read or written.

9.2.4.1 Constant power factor mode parameters

Parameters for constant power factor mode as described in Section 6.10.2 shall be available for reading and writing through a local DER communication interface. Power factor value and excitation encoding are protocol dependent (See Table 26).

TABLE 26

CONSTANT POWER FACTOR MODE PARAMETERS[39]

PARAMETER	DESCRIPTION	RANGE
Constant power factor mode enable	Enable constant power factor mode	On/Off
Constant power factor	Constant power factor setting	0.0 – 1.0
Constant power factor mode	Constant power factor mode setting	Sourcing or consuming

[39] IEEE Std. 1547-2018, Table 30

9.2.4.2 Constant reactive power mode parameters

Parameters for constant reactive power mode as described in Section 6.10.3 shall be available for reading and writing through a local DER communication interface (See Table 27).

TABLE 27

CONSTANT REACTIVE POWER MODE PARAMETERS[40]

PARAMETER	DESCRIPTION	RANGE
Constant reactive power mode enable	Enable constant reactive power mode	On/Off
Constant reactive power	Constant reactive power settings	See Table 10

9.2.4.3 Voltage-reactive power mode parameters

Parameters for voltage-reactive power mode as described in Section 6.10.4 shall be available for reading and writing through a local DER communication interface (See Table 28).

TABLE 28

VOLTAGE-REACTIVE POWER MODE PARAMETERS[41]

PARAMETER	DESCRIPTION	RANGE
Voltage-reactive power mode enable	Enable voltage-reactive power mode	On/Off
V_{Ref}	Reference voltage	0.95 - 1.05 p.u. nominal voltage
Autonomous V_{Ref} adjustment	Enable/disable autonomous V_{Ref} adjustment	On/Off
V_{Ref} adjustment time constant	Adjustment range for V_{Ref} time constant	300 s to 5,000 s
V/Q curve points	Voltage-reactive power curve points	See Table 8
Open loop response time	Time to ramp up to 90% of the new reactive power target in response to the change in voltage	1 s to 90 s

[40] IEEE Std. 1547-2018, Table 33
[41] IEEE Std. 1547-2018, Table 31

9.2.4.4 Active power-reactive power mode parameters

Parameters for active power-reactive power mode as described in Section 6.10.5 shall be available for reading and writing through a local DER communication interface. See Table 29.

TABLE 29

ACTIVE POWER-REACTIVE POWER MODE PARAMETERS[42]

PARAMETER	DESCRIPTION	RANGE
Active power – reactive power mode enable	Enable active power – reactive power mode	On/Off
P/Q curve points	Active power – reactive power curve points	See Table 11

9.2.4.5 Voltage-active power mode parameters

Parameters for voltage-active power mode as described in Section 6.11.2 shall be available for reading and writing through a local DER communication interface (See Table 30).

TABLE 30:

VOLTAGE-ACTIVE POWER MODE PARAMETERS[43]

PARAMETER	DESCRIPTION	RANGE
Voltage-reactive power mode enable	Enable voltage - active power mode	On/Off
V/P curve points	Voltage - active power curve points	See Table 12
Open loop response time	Time to ramp up to 90% of the new active power target in response to the change in voltage	0.5 s to 60 s

[42] IEEE Std. 1547-2018, Table 32
[43] IEEE Std. 1547-2018, Table 34

9.2.4.6 Voltage trip and momentary cessation parameters

Parameters for voltage trip as described in Section 8.2.1 shall be available and the momentary cessation threshold as specified in Section 6.4 may be available for information exchange through a local DER communication interface. Both settings, if applicable, shall be specified as a set of piecewise linear curves that define the regions associated with the voltage regions described in the functional description (See Table 31).

TABLE 31
VOLTAGE TRIP PARAMETERS[44]

PARAMETER	DESCRIPTION	RANGE
HV trip curve points	High-voltage shall trip curve points	See Table 15 through Table 18
LV Trip curve points	Low-voltage shall trip curve points	

9.2.4.7 Frequency trip parameters

Parameters for frequency trip as described in Section 8.3.1 shall be available for reading and writing through a local DER communication interface. Frequency trip settings shall be specified as a set of piecewise linear curves that define the regions associated with the frequency regions described in the functional description (See Table 32).

TABLE 32
FREQUENCY PARAMETERS[45]

PARAMETER	DESCRIPTION	RANGE
HF trip curve points	High-frequency shall trip curve points	See Table 14
LF Trip curve points	Low-frequency shall trip curve points	

[44] IEEE Std. 1547-2018, Table 35
[45] IEEE Std. 1547-2018, Table 36

9.2.4.8 Frequency droop parameters

Parameters for frequency droop as described in Section 6.11.3 shall be available for reading and writing through a local DER communication interface (See Table 33).

TABLE 33
FREQUENCY DROOP PARAMETERS[46]

PARAMETER	DESCRIPTION	RANGE
Overfrequncy droop db_{OF}	Frequency droop deadband for overfrequency condition	See Section 6.11.3
Underfrequncy droop db_{OF}	Frequency droop deadband for underfrequency condition	
Overfrequncy droop k_{OF}	Frequency droop per-unit frequency change for overfrequency conditions corresponding to 1 per-unit power output change	
Underfrequncy droop k_{uf}	Frequency droop per-unit frequency change for underfrequency conditions corresponding to 1 per-unit power output change	
Open loop response time	The duration from a step change in control signal input until the output changes by 90% of its final change before any overshoot	

9.2.4.9 Enter service

Parameters for enter service (ES) as described in Section 7.4.1 shall be available for reading and writing through a local DER communication interface (See Table 34).

TABLE 34
ENTER SERVICE AFTER TRIP PARAMETERS[47]

PARAMETER	DESCRIPTION	RANGE
Permit service	Able to enter or stay in service	Enable/Disable
Es voltage high	Enter service voltage high	Table 12
Es voltage low	Enter service voltage low	
Es frequency high	Enter service frequency high	
Es frequency low	Enter service frequency low	
Es delay	Enter service delay	0 – 600 s
Es randomized delay	Enter service randomized delay	1 – 1,000 s
Es ramp rate	Enter service ramp rate	1 – 1,000 s

[46] IEEE Std. 1547-2018, Table 37
[47] IEEE Std. 1547-2018, Table 39

9.2.4.10 Cease to energize and trip

A DER can be directed to cease to energize and trip by changing the permit service setting to "disabled" as described in Section 6.7.1.

9.2.4.11 Limit maximum active power

Parameters to limit maximum active power as specified in Section 6.5 shall be available for reading and writing through a local DER communication interface (See Table 35).

TABLE 35

LIMIT MAXIMUM ACTIVE POWER PARAMETERS[48]

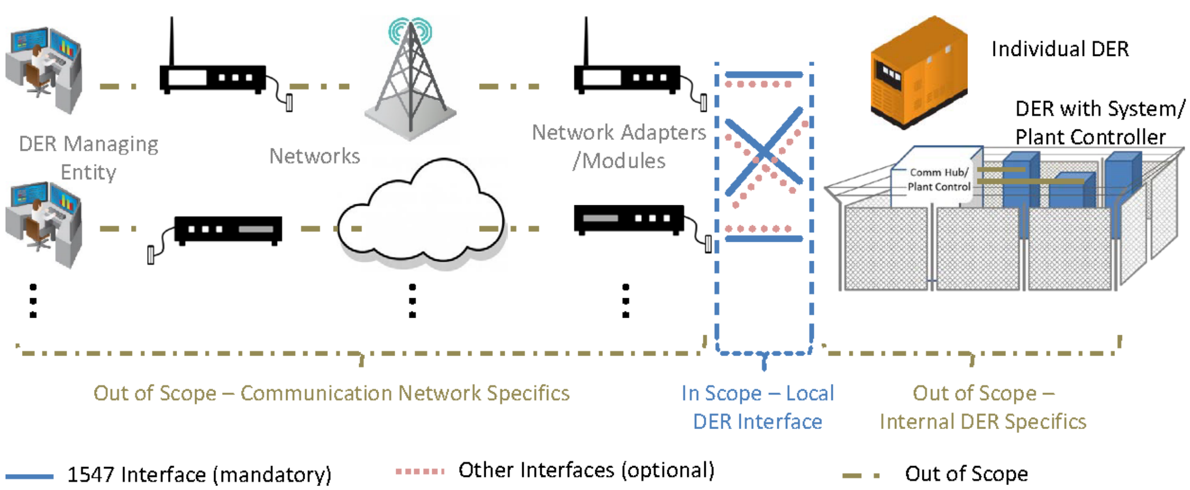
PARAMETER	DESCRIPTION	RANGE
Limit active power enable	Enable mode	On/Off
Maximum active power	Maximum active power setting	Refer to Section 6.11

9.3 COMMUNICATION PROTOCOL REQUIREMENTS

The protocol requirements set forth in this section apply at the local DER communication interface. As illustrated in Figure 10, the protocols and physical layers utilized within communication networks and within the DER may differ according to the network architecture and technology.

FIGURE 10

CONTROL PROTOCOL IN/OUT OF SCOPE MAPPING[49]



[48] IEEE Std. 1547-2018, Table 40
[49] IEEE Std. 1547-2018, Figure 4

The DER shall support at least one of the protocols specified in Table 36. The protocol to be utilized will be specified by EDTI. Additional protocols, including proprietary protocols, may be allowed under mutual agreement between EDTI and the power producer. Additional physical layers may be supported along with those specified in the table.

TABLE 36

LIST OF ELIGIBLE PROTOCOLS[50]

PROTOCOL	TRANSPORT	PHYSICAL LAYER
IEEE Std 2030.5 (SEP2)	TCP/IP	Ethernet
IEEE Std 1815 (DNP3)	TCP/IP	Ethernet
SunSpec Modbus	TCP/IP	Ethernet
	N/A	RS-485

9.4 COMMUNICATION PERFORMANCE REQUIREMENTS

Communication performance requirements for the interface to DER are set forth in Table 37. These requirements do not constrain or define the performance of various communication systems that may be utilized to integrate DER, but only apply to the DER themselves.

TABLE 37

COMMUNICATION PERFORMANCE REQUIREMENTS FOR DER INTERFACES[51]

PARAMETER	REQUIREMENT	DESCRIPTION
Availability of communication	When DER is operational	The local DER communication interface shall be active and responsive whenever the DER is operating and in a continuous operation region or mandatory operation region
Information read response time	≤ 30 s	The maximum amount of time to respond to read requests

9.5 CYBER SECURITY REQUIREMENTS

Cybersecurity is a critically important issue for DER deployments connected to broader monitoring and control communications networks. Each standardized local DER communication interface option provides different security capabilities. The interoperability and communications cyber security requirements of specific DER deployments will be based on mutual agreement considering regulatory requirements specified by the AESO.

[50] IEEE Std. 1547-2018, Table 41
[51] IEEE Std. 1547-2018, Table 42

10.0

Hosting Capacity

Hosting capacity is the amount of DER that can be added to the EEDS before control changes or system upgrades are required to safely and reliably integrate additional DER. Hosting capacity does not represent a hard limit on the amount of DER that can be added to the EEDS. As upgrades are implemented or system is reconfigured, the hosting capacity of the system increases or decrease.

Hosting capacity is highly relational, dependent on a number of factors, including:

- The characteristics of the DER systems, such as whether advanced inverter settings are utilized, the system size, and where it is located on the circuit
- The location and time-varying behaviour of all DERs on the circuit, such as distributed storage
- The existing equipment on a circuit at any given time, which will evolve over time depending on investments made by EDTI and power producers or developers
- The distribution planning practices used by EDTI, especially, how to determine when upgrades or other mitigations are required.

10.1 SUBSTATION TRANSFORMERS AND ON LOAD TAP CHANGERS (OLTCS)

Substation transformers are the back-bone of the EEDS, and the expected life of substation transformers are 30 to 40 years or longer, if they are well maintained and lightly loaded. Increased loss and thermal cycling reduce transformer life. Small increases in the excitation voltage above the limits leads to significant increase to magnetizing current and harmonics. The core losses impact the temperature-rise and the life of the transformers. When comparing the results of various operating conditions, it is reverse active and reactive power flow that has the biggest negative impact on the transformers.. There are restrictions on power flow without the loss of transformer life, which determines the hosting capacity of the transformers.

Voltage fluctuation increases with the increase of DER penetration level. Consequently, significant increase in tap change positions will occur. EDTI reserves the right to use the on load tap changer OLTC operation as a limit for hosting capacity on a substation transformer.

There are types (2-winding vs 3-windings) of substation transformers with ratings, which determines hosting capacities through different criteria. If the DER penetration exceeds the hosting capacity limited by a substation transformer, EDTI will increase the hosting capacity through alternative means of mitigation.

10.2 CIRCUITS

Every distribution circuit is unique due to the combination of voltage class, conductor type, topology, and other circuit characteristics. The circuit design itself provides part of the uniqueness, but the customer dynamics also play a role. As a result of this diversity, all circuits will have a unique response to DERs and therefore a unique amount of DERs that can be accommodated before facing a negative impact to the circuit. This circuit hosting capacity will be dependent on many factors, including but not limited to circuit configuration, DER deployments, and specific operating thresholds defined by EDTI.

The circuit hosting capacity is rooted in two key areas that are critical for ensuring effective DER integration:

- Voltage - considering over and undervoltages (primary and secondary), voltage regulation, changes to equipment operation (regulators and OLTC), switched capacitor banks; and
- Protection - considering protection coordination issues due to changes in fault current including: relay desensitization, sympathetic tripping, and increased fault duty.

10.3 DISTRIBUTION TRANSFORMERS

Similar to the 2-winding substation transformers, a small increase in the excitation voltage above the limits leads to significant magnetizing current increase and harmonics. The core losses impact the temperature-rise and the life of the transformers. When comparing the results of various operating conditions, it is reverse active and reactive power flow that has the biggest negative impact on the transformers. There are restrictions on power flow without the loss of transformer life, which determines the hosting capacity of the transformers.

EDTI will assess the condition of a transformer which a new DER is proposed to be connected to based on industry best practices. If the transformer cannot accommodate the new DER interconnection, EDTI may upgrade or replace the transformer or provide alternate means to mitigate the hosting capacity requirements.

11.0

DER Connection to Secondary Networks

IEEE Std. 1547-2018 provides mandatory requirements for the interconnection of DER with EEDS. It focuses primarily on radial circuit interconnections. For DER interconnected on secondary networks, not only all of IEEE Std. 1547-2018 requirements need to be satisfied but also recommendations and guidance for DER interconnected on secondary networks provided by IEEE Std. 1547.6-2011 need to be followed .

Network Protectors (NPs) shall not be used to connect, separate, switch, serve as breaker failure backup, or in any manner isolate a network or network primary circuit to which DER is connected from the remainder of the network, unless the protectors are rated and tested per applicable standards for such an application.

Unless otherwise specified by EDTI, DER installations on a network, using an automatic transfer scheme in which load is transferred between the DER and the EEDS in a momentary make-before break operation, shall meet all the requirements of this Technical Requirement regardless of the duration of paralleling. Power flow during this transition shall be positive from the EEDS to the load and the DER.

DER on grid or spot networks shall have provisions to:

- monitor instantaneous power flow at the PCC of the DER interconnected to the secondary grid or spot network for reverse power relaying, minimum import relaying, dynamically controlled inverter functions and similar applications to prevent reverse power flow through network protectors.
- maintain a minimum import level at the PCC as determined by EDTI.
- control DER operation or disconnect the DER from the EEDS based on an autonomous setting at the PCC and/or a signal sent by EDTI.

DER on grid or spot networks shall not

- cause any NP to exceed its loading or fault-interrupting capability.
- cause any NP to separate dynamic sources.
- cause any NP to connect two dynamic systems together.
- cause any NP to operate more frequently than prior to DER operation.
- prevent or delay the NP from opening for faults on the EEDS.
- delay or prevent NP closure.
- energize any portion of the secondary network on the EEDS when the network is de-energized.
- require the NP settings to be adjusted except by consent of EDTI.
- prevent reclosing of any network protectors installed on the network. This coordination shall be accomplished without requiring any changes to prevailing network protector clearing time practices of EDTI.

The responsibility of the costs associated with the controls, installation, maintenance, etc. will be determined on case-by-case basis.

11.1 SECONDARY GRID NETWORKS

In addition to the requirements in Section 11, DER on secondary grid networks shall not cause an islanding condition within that network.

In addition to the requirements in Section 11, in the event of an adjacent circuit fault, network protector master relays shall not be actuated by the presence of DER. The interconnected DER shall be coordinated with NP relay functions and shall be evaluated by EDTI to ensure network reliability.

When the DER output is always less than the facility load (demand) and a minimum load level can be maintained through the NPs, power flow is always from the grid into the facility. Under normal operating conditions, and when the required minimum load level through the NPs can be maintained, DER output simply displaces load that would otherwise be supplied by the grid.

Under conditions of network system fault, the DER current contribution shall cease. The DER shall either cease to provide output current or be disconnected on the occurrence of a system anomaly that causes DER output current to exceed its full load rating. For induction and synchronous technology under fault current conditions, certain advanced protection systems may be able to disconnect the DER in up to 3 cycles and limit the current contribution. However, since this generation technology usually has three-phase output, additional protection should be included to provide the same speed of separation for the anomalies of single-phasing and excessive unbalanced current flows from the DER.

On a grid network, the backfeed from a DER for an adjacent circuit fault will be seen by all of the NPs. This condition may cause all of the NPs to operate in accordance with the current division among the multiple paths and the level of reverse current. These reverse current flows are seen simultaneously by the NP master relays and the DR protection. Once an NP's master relay sees the current, it will operate and the NP will trip even if the DER was isolated very fast, and prior to the opening of the NP. The only apparent way to provide coordination for higher DER penetration would be to delay the operation of the NP to allow operation of the DER breaker and the reset of the NP master relay. However, delaying the NP for reverse power flow may increase the potential damage to the circuit under a network circuit fault condition. Therefore, EDTI does not allow NP operations with time delay on grid networks. Consequently, EDTI only allows inverter-based DER to be installed on the grid networks.

11.2 SECONDARY SPOT NETWORKS

In addition to the requirements in Section 10, connection of the DER to the EEDS is only permitted if the network bus is already energized by more than 50% of the installed network protectors.

DER interconnection should not cause inadvertent operation of the NPs. The DERs should be operated so as to maintain a preset value of positive power flow from the network into the host facility. This preset value should be as mutually agreed to by EDTI and the power producers.

The DER should cease to provide power whenever power flow into the facility is less than the value agreed and for abnormal conditions as agreed to by EDTI and power producers. This action should have no intentional delay.

The spot networks can accept either inverter or rotating machine generation after the existing equipment capability is thoroughly evaluated and replaced with appropriately rated equipment, if necessary.

11.3 PROTECTION AND FAULT ANALYSIS

The presence and operation of DERs on the spot network will initiate a detailed protection review to be completed by EDTI. This work can be subdivided into three groups as shown below (EEDS primary, EEDS secondary, and customer secondary).

11.3.1 Faults on EEDS primary

Under fault conditions on the EEDS primary system, the customer's underpower relay shall be coordinated with the sensitive time trip of the NP relay such that only the NP on the faulted circuit opens and the underpower relay does not trip the DERs.

Under fault conditions on the EEDS primary system on an adjacent primary circuit, a coordination review shall be completed. If coordination is inadequate, either the settings must be changed or the old relays will be replaced with approved relays.

11.3.2 Faults on EEDS secondary

Under fault conditions on the secondary within EDTI jurisdiction, the NPs will remain closed.

11.3.3 Faults on customer secondary

Under fault conditions on customer's side of the point of common coupling, the NPs will remain closed.

Under fault conditions on the customer's side − breakers separating all generation must open immediately without any intentional time delay.

11.4 MINIMUM LOAD CONTROLS

The DERs shall meet the minimum import requirements below:

a. A redundant EDTI-approved underpower (Device 37) relay is required. This device should be either a three-phase relay set for single-phase operation or three single-phase relays. All three phases need to be monitored such that if any one phase does not meet the minimum import requirement the underpower relay will trip the DER.

b. The device will have the settings of ten percent (10%) of the nameplate rating of the largest single network transformer serving the EDTI secondary spot network bus where the DER is installed.

c. If the minimum import flow is not met, the DER must trip, with no intentional time delay, to ensure the DER trip prior to the network protectors. Redundant protection of the net import minimum power must be provided. A DER trip setting of 15 cycles or less is required.

12.0

DER Facility Design

12.1 DISCONNECTING MEANS

Disconnecting means shall be provided in accordance with the Canadian Electrical Code (CEC), Part I. For DER systems with multiple DER units, one disconnecting means shall have the capability of isolating all DERs simultaneously from the EEDS.

Disconnecting means shall be provided to simultaneously disconnect all ungrounded conductors of an interconnected system from all circuits supplied by the DER.

Disconnecting means shall:

a. be capable of being energized from both sides;

b. plainly indicate whether it is in the open or closed position;

c. have contact operation verifiable by direct visible means;

d. have provision for being locked in the open position;

e. conform to Sections 14, 28 and 36 of CEC Part I, if it includes an overcurrent device;

f. be capable of being opened at rated load;

g. be capable of being closed with safety to the operator with a fault on the system;

h. disconnect all ungrounded conductors of the circuit simultaneously;

i. bear a warning to the effect that inside parts can be energized when the disconnecting means is open; and

j. be readily accessible.

The power producer shall follow EDTI's switching, clearance and tagging procedures. EDTI shall instruct the power producers on these procedures.

12.2 INTERCONNECTION TRANSFORMER

For customer-owned transformers, the transformer winding configuration shall be reviewed for acceptance by EDTI.

12.3 DRAWINGS REQUIRED

Prior to parallel operation or momentary parallel operation of a DER, EDTI shall approve the power producer's protective function and control diagrams. Sample single-line diagrams are shown in Appendix III.

12.4 METERING

12.4.1 General

Metering equipment must comply with Measurement Canada requirements and be approved by EDTI.

The metering equipment must be:

- suitable for use in the environmental conditions reasonably expected to occur at the installation site over the course of a typical year
- appropriate for the power system characteristics reasonably expected to exist at the installation site under all power system conditions and events

The primary side of the interconnection transformer, which is the side connected to EDTI's system, is the metering billing point for the DER export conditions. The low side of the interconnection transformer, which is the side connected to the power producer's facilities, is the metering billing point for the DER's import conditions. On all installations where the metering equipment is installed on the low side of the interconnecting transformer, transformer loss compensation, when required, will be applied in EDTI's billing system of record at a rate of 1% except if superseded by AESO regulation or if supplanted by a customer-specific loss factor approved by a professional electrical engineer or registered electrical technologist in the Province of Alberta and submitted to and approved by EDTI.

12.4.2 Metering requirements

Metering requirements will be determined by EDTI based on the type and size of a DER. EDTI will provide and install meters at DER facilities (all meters will be bidirectional. Commercial/ industrial meters will have four quadrants capability). The installation may require additional metering cabinets, metering cells and a dedicated 120 Volt AC supply to each meter cabinet.

The power producer shall be required to cover the costs of additional equipment, if applicable. EDTI shall own, and have safe access to all metering equipment, including instrument transformers at all metering locations. The power producer will also be required to comply with all the metering requirements specified in EDTI's Customer Connection Guide.

12.4.3 Measurement transformers

The applicable winding(s) of the current and potential instrument transformers must:

- be approved by Measurement Canada for revenue metering
- be burdened to a degree that does not compromise the accuracy required by this guideline
- have an accuracy class rating that equals or exceeds the values specified in Table 38.

TABLE 38

MEASUREMENT TRANSFORMER ACCURACY

METERING POINT CAPACITY (MVA)	WATT HOUR METER ACCURACY CLASS	VAR HOUR METER ACCURACY CLASS	MEASUREMENT TRANSFORMER ACCURACY CLASS
10 and above	0.2%	0.5%	0.3%
Below 10	0.5%	1.0%	0.3%

13.0

DER Interconnection Studies

The interconnection of any DERs to the EEDS requires careful attention to the impact on system assets and customers. This is true whether the source is landfill gas to energy generation, community PV, battery storage, or any other type of DERs. As DER penetration continues to increase at the distribution level, it is important to apply a systematic evaluation process to determine the adequacy of the existing system to accommodate new DERs.

A DER interconnection study includes:

- Voltage and thermal limitations in a worst case steady-state condition
- Distribution system protection schemes, protection sensitivity, reclosing, etc.
- Anti-islanding protection
- TOV and TRV

The studies determine specific modifications required to the existing system to ensure safe and reliable operation and to address any concerns identified within the DER interconnection studies.

Any DERs with rating of or over 150 kW for 3-phase or 50 kW for 1-phase or as EDTI determines is necessary require DER interconnection studies. The steady-state studies will be performed by EDTI while the transient studies (TOV, TRV and anti-islanding) for DERs with rated kVA ≥ 1,000 will be performed by the power producers. The power producers shall bear the costs for the transient studies.

To conduct the studies, the power producers are required to provide following information in Sections 13.1 to 13.3 to EDTI.

13.1 INVERTER-BASED DERS

- Inverter make and model
- Phases (Single or Three)
- Rated apparent power (kVA)
- Rated voltage (V)
- Active power rating (kW)
- Reactive power rating (kVar)
- Minimum power factor (%)
- Short-circuit fault contribution (% of rated current or % of active generation)
- Inverter rated DC voltage (V)
- DC capacitor capacitance value (μF)
- Internal losses (W/phase)
- Grid-side coupling filter or transformer resistance (Ω)
- Grid-side coupling filter or transformer inductance (H)

- Control type
  - Volt-var Control
  - Volt-Watt Control
  - Watt-Power Factor Control
  - Dynamic Reactive Current Control
  - Maximum Generation Level Control
  - Adjust Power Factor Control
- Rise limit (%/min or W/s or var/s)
- Fall limit (%/min or W/s or var/s)

13.2 SYNCHRONOUS GENERATORS

- Machine make and model
- Phases (1 or 3)
- Number of poles
- Rated voltage (kV)
- Rated apparent power (kVA)
- Rated power factor (%)
- Positive sequence resistance R_1 (Ω or p.u.)
- Positive sequence reactance X_1 (Ω or p.u.)
- Negative sequence resistance R_2 (Ω or p.u.)
- Negative sequence reactance, X_2 (Ω or p.u.)
- Zero sequence resistance R_0 (Ω or p.u.)
- Zero sequence reactance, X_0 (Ω or p.u.)
- Transient resistance R'_1 (Ω or p.u.)
- Sub-transient resistance R''_1 (Ω or p.u.)
- Synchronous direct-axis impedance, X_d (Ω or p.u.)
- Synchronous quadrature-axis impedance, X_q (Ω or p.u.)
- Transient direct-axis reactance, X_d' (Ω or p.u.)
- Transient quadrature-axis reactance X'_q (Ω or p.u.)
- Open-circuit direct-axis transient time constant, T_d0' (s)
- Short-circuit quadrature-axis transient time constant, T_q' (for cylindrical-rotor machines)
- Short-circuit direct-axis transient time constant, T_d'
- Subtransient direct-axis impedance, X_d'' (Ω or p.u.)
- Subtransient quadrature axis impedance, X_q'' (Ω or p.u.)
- Short-circuit direct-axis subtransient time constant, T_d''

- Short-circuit quadrature-axis subtransient time constant, T_q''
- Open-circuit direct-axis subtransient time constant, T_{d0}''
- Open-circuit quadrature-axis subtransient time constant, T_{q0}''
- Exciter time constant, T_e
- Armature short-circuit time constant, T_a
- Stator resistance, r_s
- Field resistance, r_f
- Total (generator plus prime mover) moment of inertia, J
- Saturation coefficients SGU and SGL
- Inertia of all rotating mass (MW-s/MVA or kg-m^2)
- Damping constant (pu)
- Grounding impedance R_g and X_g (Ω)

13.3 INDUCTION GENERATORS

- Machine make and model
- Phases (Single or Three)
- Rated apparent power (kVA)
- Rated power factor (%)
- Rated L-L voltage (kV)
- Stator resistance, R_S
- Stator leakage reactance, X_{LS}
- Rotor resistance, R_r
- Rotor leakage inductance, X_{LR}
- Magnetizing reactance, X_m
- Mutual inductance, L_M
- Sub-transient resistance R” (Ω or p.u.)
- Sub-transient reactance X” (Ω or p.u.)
- Total (generator plus prime mover) moment of inertia, J
- Number of poles, P
- Efficiency (%)
- Rated speed (RPM)
- ANSI Motor Group

The power producers shall provide additional DER information for transient studies if it is required by the engineers who performed the studies.

14.0

DER Evaluations and Commissioning Tests

14.1 INTRODUCTION

EDTI is responsible for ensuring that reasonable precautions are taken when allowing DERs to interconnect to the EEDS. In addition to the overall project review and various system studies (preliminary interconnection studies, harmonic studies, TOV/TRV studies, etc.), DER projects with aggregate nameplate rating over 250 kVA are subject to EDTI witnessing aspects of the commissioning tests (at EDTI's discretion). The power producer shall notify EDTI in writing at least two weeks before the planned initial energizing and interconnection tests.

Note: EDTI has the option of witnessing the commissioning tests of any DER project, regardless of size.

The type, commissioning and periodic tests, and evaluations shall be performed to confirm that the interconnection and interoperation functions of equipment and systems interconnecting DERs with the EEDS conform to IEEE Std. 1547-2018 and CSA C22.3 No.9:20.

The witnessing of tests is the direct observation, by an EDTI representative, of testing performed by the power producer or the professional personnel hired by the power producer.

14.1.1 Full or partial compliance

A **DER unit** is defined as a fully compliant DER that does not require supplemental DER devices to meet the IEEE Std. 1547 requirements. A DER system is defined as a system consists of DER unit(s) and supplemental DER device(s) that is type tested as a system and installed in accordance with the DER manufacturer's instructions and that, as a whole, is fully compliant with IEEE Std. 1547-2018.

A **partially compliant DER unit** is defined as a unit that does not meet all of the IEEE Std. 1547-2018 requirements and requires supplemental DER device(s) and/or may require supplemental evaluation by EDTI to verify compliance to meet the requirements of IEEE Std. 1547-2018.

A **DER composite** is defined as a system that consists of partially compliant DER components and supplemental DER device(s), and requires detailed design evaluation, installation evaluation, and commissioning tests to determine full compliance to IEEE Std. 1547-2018 requirements.

Design evaluation of the DER composite system shall determine the level of verification required to verify compliance. The design and installation evaluations and commissioning tests triggered by the partial compliance are to be limited to the related requirements impacted by the supplemental device(s) used to achieve full compliance including adverse impacts of those devices on other IEEE Std. 1547-2018 requirements.

14.2 DER VERIFICATION PROCESS

This section summaries the steps in the system verification process. Power producers shall follow the instruction about each step described in clause 8 of IEEE Std. 1547.1-2020.

Table 39 provides a summary of the test and verification process.

TABLE 39

SUMMARY OF TESTS AND VERIFICATIONS[52]

Figure 11 outlines the test and verification process for systems with the RPA at the PoC.

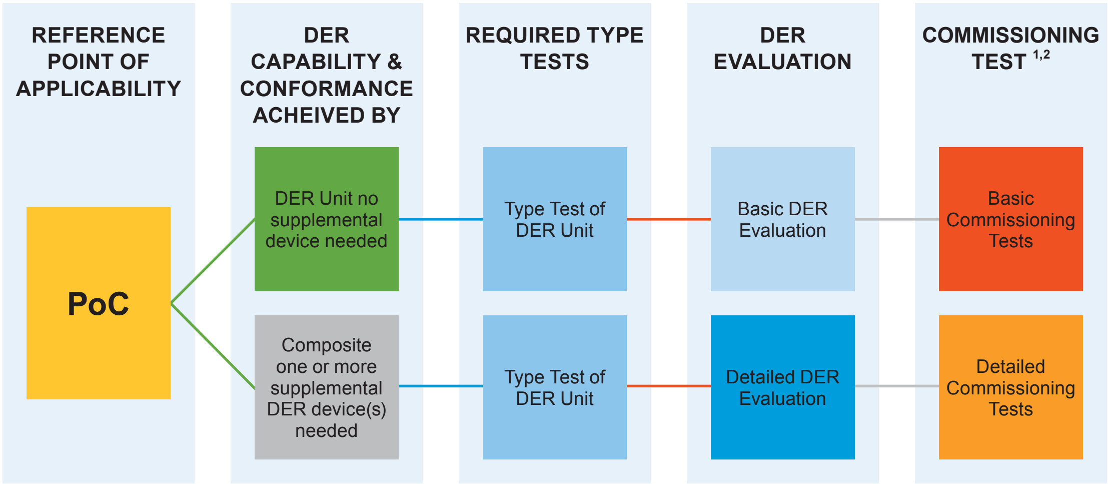
TEST OR EVALUATION	DESCRIPTION
Type test(s) of DER unit(s)	A *DER unit* that is type tested and compliant with the standard.
Type test of *DER system*	A DER system that is composed of *DER units* and *supplemental DER devices* that are type tested as a system and that, as a whole, is compliant with the standard.
Basic *DER evaluation*	A basic DER *design evaluation* shall be limited to verify that the DER has been designed with the proper components and connections. A basic DER as-built *installation evaluation* shall verify that the DER has been installed with the proper components and connections and all settings are as detailed in the project documentation.
Detailed *DER evaluation*	A detailed DER *design evaluation* shall include an engineering review of the chosen components and may require modelling and simulation of the composite system. A detailed DER as-built *installation evaluation* shall verify that the DER has been installed with the proper components and connections and all settings are as detailed in the project documentation.
Basic *commissioning test*	A basic *commissioning test* may include visual inspection and an operability test on the isolation device. The basic *commissioning* test shall be determined from the *design evaluation*.
Detailed *commissioning test*	A detailed *commissioning test* shall include a basic *commissioning test* and functional tests to verify compliant system performance and interoperability of a combination of devices forming a system to verify that the devices are able to operate together as a system. The detailed *commissioning test* shall be determined from the *design evaluation*.

[52] IEEE Std. 1547.1-2020, Table 71

FIGURE 11

TEST AND VERIFICATION PROCESS FOR SYSTEMS WITH RPA AT POC[53]

Figure 12 outlines the test and verification process for systems with the RPA at the PCC.



1 As applicable, may depend on DER Design Evaluation
2 Some type tests may be performed during commissioning and under special circumstances

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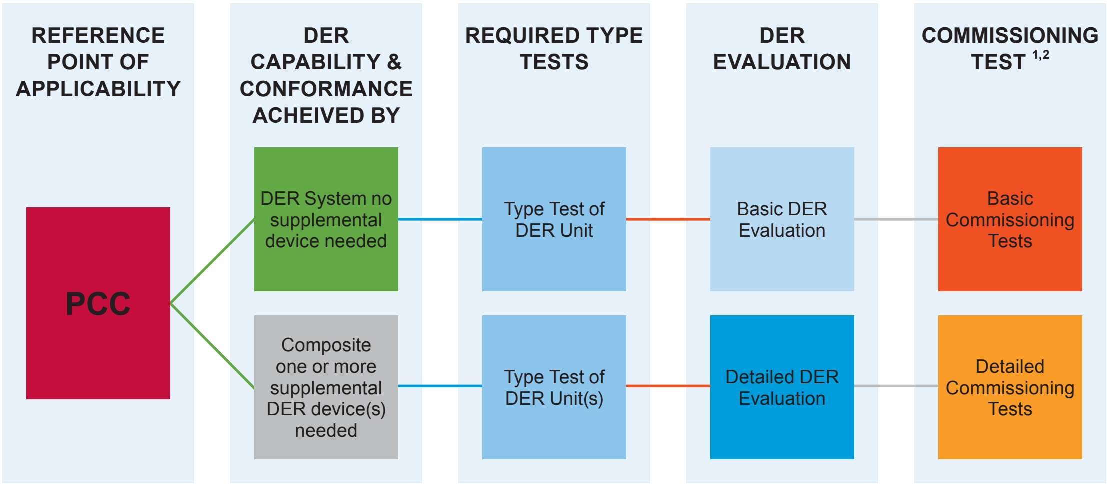
[53] IEEE Std. 1547.1-2020, Figure 17

FIGURE 12
TEST AND VERIFICATION PROCESS FOR SYSTEMS WITH RPA AT PCC[54]

14.2.1 Type tests



1 As applicable, may depend on DER Design Evaluation
2 Some type tests may be performed during commissioning and under special circumstances

Type tests are performed on a specific DER unit or DER system. The tests are performed on a representative DER unit or DER system, either in the factory or at a nationally recognized testing laboratory (NRTL). Type test results from a DER within a product family of the same design, including hardware and software, are allowed as representative of other DERs within the same product family with power ratings between 50% to 200% of the tested DER.

The NRTL or other applicable testing body shall produce a summary report summarizing the results of the type testing. The test summary report shall include the equipment nameplate information described in Table 40 and shall identify all evaluated functions including any associated ranges of adjustment within the range of allowable settings. The template for results reporting is posted on the IEEE Standards Association's website at: https://standards.ieee.org/downloads.html.

[54] IEEE Std. 1547.1-2020, Figure 18

TABLE 40

NAMEPLATE INFORMATION

PARAMETER	DESCRIPTION
Active power rating at unity power factor (nameplate active power rating)	Active power rating in watts at unity power factor
Active power rating at specified over-excited power factor	Active power rating in watts at specified over-excited power factor
Specified over-excited power factor	Over-excited (leading) power factor as described in 6.10.1
Active power rating at specified under-excited power factor	Active power rating in watts at specified under-excited power factor
Specified under-excited power factor	Under-excited power factor as described in 6.10.1
Apparent power maximum rating	Maximum apparent power rating in voltamperes
Normal operating performance grade	Indication of reactive power and voltage/power control grade as described in 5.3
Abnormal operating performance category	Indication of voltage and frequency ride-through capability grade as described in 5.3
Reactive power injected maximum rating	Maximum injected reactive power rating in vars
Reactive power absorbed maximum rating	Maximum absorbed reactive power rating in vars
Active power charge maximum rating	Maximum active power charge rating in watts
Apparent power charge maximum rating	Maximum apparent power charge rating in voltamperes. May differ from the apparent power maximum rating
AC voltage nominal rating	Nominal AC voltage rating in RMS volts
AC voltage maximum rating	Maximum AC voltage rating in RMS volts
AC voltage minimum rating	Minimum AC voltage rating in RMS volts
Supported control mode functions	Indication of support for each control mode function
Reactive susceptance that remains connected to the EEDS in the *cease* to *energize* and trip state	Reactive susceptance that remains connected to the EEDS in the *cease* to *energize* and trip state
Manufacturer	Manufacturer
Model	Model
Serial number	Serial number
Version	Version

14.2.2 Commissioning tests and verifications

14.2.2.1 Basic and detailed commissioning test

A basic commissioning test includes visual inspection and several tests of key functions of the interconnection for DERs certified to UL1741 SA or SB without a supplemental DER device or devices. The basic commissioning test requirements are shown in Table 41 which includes Design Evaluation (DE), Installation Evaluation (IE) and Commissioning Test (CT) requirements.

TABLE 41

VERIFICATION SUMMARY FOR POC UNITS

SECTION	TITLE	DE – CONFIRM PERTINENT *TYPE TEST* AND *PRODUCTION TEST* REQUIREMENTS MET	DE – CONFIRM WITH PROTECTION AND IMPACT STUDY	IE – VERIFY INSTALLATION MATCHES *DESIGN EVALUATION*	IE – VERIFY INSTALLATION SETTINGS	CT – ON-OFF TEST	CT – VERIFY SYNCHRONI-ZATION	CT – VOLTAGE AND FREQUENCY TEST	CT – POWER QUALITY TESTS
6.4	Reference points of applicability	R	NR	R	NR	NR	NR	NR	NR
6.5	Applicable voltages	R	NR	R	NR	NR	NR	NR	NR
6.9	Inadvertent energization of the EEDS	NR	NR	R	R	D	NR	NR	NR
7.4.2	Performance During Enter Service	R	NR	R	NR	D	NR	NR	NR
7.5	Synchronization	R	NR	R	NR	NR	D	NR	NR
6.13	Integration with EEDS grounding	R	R	R	NR	NR	NR	NR	NR
6.11.2	Voltage-Active Power Mode	R	NR	NR	R	NR	NR	NR	NR
7.2, 7.3	EEDS Faults and open phase conditions	R	R	NR	NR	NR	NR	NR	NR
7.2	EEDS reclosing coordination	R	R	NR	NR	NR	NR	NR	NR
8.2.1	Mandatory voltage tripping requirements	R	R	NR	R	NR	NR	NR	NR
8.2.2.3	Low-voltage ride-through performance	R	R	NR	NR	NR	NR	R[56]	NR
8.3.1	Mandatory frequency tripping requirements	R	R	NR	R	NR	NR	R[12]	NR
6.12.3	Flicker	NR	R	NR	NR	NR	NR	NR	R
6.13.1	Limitation of overvoltage contribution	NR	R	R	NR	NR	NR	NR	NR
7.6	Unintentional islanding	R	R	NR	NR	NR	NR	NR	NR
11.1	Distribution secondary grid networks	NR	R	R	NR	R	R	NR	NR
11.2	Distribution secondary spot networks	NR	R	R	NR	R	R	NR	NR

Legend: R = required evaluation or test, NR = no requirement.

[55] IEEE Std. 1547.1-2020, Table 72
[56] Signal injection test method is used if the DER unit has provisions for this method.

A detailed functional commissioning test includes what required for a basic commission test and functional tests to verify the combination of devices are able to operate together as a system and meet the applicable requirements of IEEE Std. 1547-2018. This test is for inverter-based DERs with a supplemental DER device or devices[57] and machine-based DERs.

Detailed information about detailed commissioning test can be found in Clause 8 of IEEE Std. 1547.1-2020. The detailed commissioning test requirements are shown Appendix VI. The commissioning test report shall in the format described in Section 14.2.1.

14.2.2.2 Verification required for all DERs

EDTI will follow next steps for all DER verifications:

a. Review owner's project requirements (OPR), project specifications, and the requirements in this Technical Requirement for information specifically related to the DER unit's type test requirements, production test requirements, and project-specific settings and configurations.

b. Determine the RPA for the DER per Section 6.4 in this TR.

c. Verify that all settings meet requirements set by EDTI.

d. Verify the operating modes that will be implemented at the time of commissioning.

    i. Verify the system is capable of meeting the applicable baseline grade or supplemental grade as specified by this TR. Document required settings for the operation.

    ii. Record all settings for response to abnormal voltage and frequency conditions, and verify compliance with the requirements in this TR.

    iii. Record all enabled voltage/power control functions and settings.

    iv. Confirm operational coordination with reclosers on the EEDS where applicable.

    v. Confirm after-trip-return-to-service operation requirements (the same as entering service as descried in Section 7.4).

    vi. Verify unintentional islanding detection operation and state interval time from initiation of the island to cease-to-energize.

    vii. May review power systems simulation and models to verify DER characteristics were properly characterized. Include summary and source data for any engineering verification of the chosen components or modelling and simulation of the DERs forming a system.

e. For requirements that are supported by a protection study, confirm DER settings and connection configuration with the study.

Considering all of the above, list the elements of the DER functionality that must be verified during commissioning.

[57] A basic Commissioning test may be acceptable based on the agreement between EDTI and the power producer.

14.3 PERIODIC TESTS

Periodic tests are tests and verifications, according to a scheduled time period or other criteria, that confirm that one already interconnected device or combination of devices forming a system meets the interconnection and interoperability requirements of this standard.

Periodic test requirements and intervals for all interconnection-related protective functions and associated batteries shall be provided by interconnection equipment manufacturers and approved by EDTI. Frequency of retesting shall be determined by manufacturer requirements. Periodic test reports or a log for inspection shall be maintained by the power producer.

For systems in the field, replacement of DER equipment with substitutive components compliant to CSA C22.3 No.9:20 or IEEE Std. 1547-2018 are allowed and not invalidate previous type test and production test results. The EDTI may still require commissioning testing on any equipment replaced.

Information describing facility changes such as software, firmware and hardware, shall be available to the EDTI through the interoperability requirements of Section 9. Reverification of the interconnection and interoperability requirements of this Technical Requirement may be required when any of the following events occur:

- functional software or firmware changes have been made on the DER.
- any hardware component of the DER has been modified in the field or has been replaced or repaired with parts that are not substitutive components compliant with this standard.
- protection settings have been changed after factory testing.
- protection functions have been adjusted after the initial commissioning process.

15.0

Additional Information

15.1 REFERENCES

[1] CSA C22.3 No. 9:20 *Interconnection of distributed energy resources and electricity supply systems*

[2] IEEE Std. 1547-2018 *IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces*

[3] IEEE Std. 1547.1-2020 *Standard Conformance Test Procedures for Equipment Interconnecting Distributed Energy Resources with Electric Power Systems and Associated Interfaces*

[4] IEEE Std. 1547.6-2011 *IEEE Recommended Practice for Interconnecting Distributed Resources with Electric Power Systems Distribution Secondary Networks*

[5] IEEE Std. C62.92.1-2016 *IEEE Guide for the Application of Neutral Grounding in Electrical Utility Systems--Part I: Introduction*

[6] IEEE Std. C37.011-2019 *IEEE Guide for the Application of Transient Recovery Voltage for AC High-Voltage Circuit Breakers with Rated Maximum Voltage above 1000 V*

[7] IEEE Std. C37.90.2-2004 *Standard for Withstand Capability of Relay Systems to Radiated Electromagnetic Interference from Transceivers*

[8] CSA IEC 61000-4-3:21 *Electromagnetic compatibility (EMC) - Part 4-3: Testing and measurement techniques - Radiated, radio-frequency, electromagnetic field immunity test*

[9] CSA IEC 61000-4-12:19 *Electromagnetic compatibility (EMC) - Part 4-12: Testing and measurement techniques - Ring wave immunity test*

[10] CAN/CSA-IEC 61000-4-5:08 *Electromagnetic compatibility (EMC) – Part 4-5: Testing and measurement techniques – Surge immunity test*

[11] CAN/CSA-CEI/IEC 61000-4-4-06 (R2011) *Electromagnetic Compatibility (EMC) - Part 4-4: Testing and Measurement Techniques - Electrical Fast Transient/Burst Immunity Test*

[12] IEEE Std. C57.13-2016 *IEEE Standard Requirements for Instrument Transformers*

[13] CAN/CSA-C60044-6-07 (R2011) *Instrument Transformers - Part 6: Requirements for Protective Current Transformers for Transient Performance*

[14] CSA C235:19 *Preferred voltage levels for AC systems up to 50 000 V*

[15] IEEE Std. C62.92.6-2017 *IEEE Guide for Application of Neutral Grounding in Electrical Utility Systems, Part VI—Systems Supplied by Current-Regulated Sources*

[16] AESO DER Roadmap Integration Paper: *DER Ride-Through Performance Recommendations*

APPENDIX I

IIEEE DEVICE NUMBERS (SEE SECTION 7.1)

15.2 APPENDIX I: IIEEE DEVICE NUMBERS (SEE SECTION 7.1)

In the design of electrical power systems, the IEEE device numbers identify features of a protective device such as relay or circuit breaker. Device numbers are used to identify functions of devices shown on a schematic diagram.

One physical device may correspond to one function number, for example "Isolating Switch", or a single physical device may have many function numbers associated with it, such as a microprocessor numerical protective relay. Suffix & prefix letters may be added to further specify purpose & function of a device.

DEVICE NO.	DESCRIPTION
1	Master Element
2	Time Delay Starting or Closing Relay
3	Checking or Interlocking Relay
4	Master Contactor
5	Stopping
6	Starting Circuit Breaker
7	Rate of Change Relay
8	Control Power Disconnecting Device
9	Reversing Device
10	Unit Sequence Switch
11	Multi-function Device
12	Overspeed Device
13	Synchronous-speed Device
14	Underspeed Device
15	Speed – or Frequency, Matching Device
16	Data Communications Device
17	Shunting or Discharge Switch
18	Accelerating or Decelerating Device
19	Starting to Running Transition Contactor
20	Electrically Operated Valve
21	Distance Relay
22	Equalizer Circuit Breaker
23	Temperature Control Device
24	Volts Per Hertz Relay

DEVICE NO.	DESCRIPTION
25	Synchronizing or Synchronism-Check Device
26	Apparatus Thermal Device
27	Undervoltage Relay
28	Flame detector
29	Isolating Contactor or Switch
30	Annunciator Relay
31	Separate Excitation
32	Directional Power Relay or Reverse Power Relay
33	Position Switch
34	Master Sequence Device
35	Brush-Operating or Slip-Ring Short-Circuiting Device
36	Polarity or Polarizing Voltage Devices
37	Undercurrent or Underpower Relay
38	Bearing Protective Device
39	Mechanical Condition Monitor
40	Field (over/under excitation) Relay
41	Field Circuit Breaker
42	Running Circuit Breaker
43	Manual Transfer or Selector Device
44	Unit Sequence Starting Relay
45	Abnormal Atmospheric Condition Monitor
46	Reverse-phase or Phase-Balance Current Relay
47	Phase-Sequence or Phase-Balance Voltage Relay

Device No.	Description
48	Incomplete Sequence Relay
49	Machine or Transformer, Thermal Relay
50	Instantaneous Overcurrent Relay
51	AC Inverse Time Overcurrent Relay
52	AC Circuit Breaker
53	Exciter or DC Generator Relay
54	Turning Gear Engaging Device
55	Power Factor Relay
56	Field Application Relay
57	Short-Circuiting or Grounding Device
58	Rectification Failure Relay
59	Overvoltage Relay
60	Voltage or Current Balance Relay
61	Density Switch or Sensor
62	Time-Delay Stopping or Opening Relay
63	Pressure Switch
64	Ground Detector Relay
65	Governor
66	Notching or Jogging Device
67	AC Directional Overcurrent Relay
68	Blocking Relay
69	Permissive Control Device
70	Rheostat
71	Liquid Level Switch
72	DC Circuit Breaker
73	Load-Resistor Contactor
74	Alarm Relay
75	Position Changing Mechanism
76	DC Overcurrent Relay
77	Telemetering Device
78	Phase-Angle Measuring Relay or “Out-of-Step” Relay
79	AC Reclosing Relay

Device No.	Description
80	Flow Switch
81	Frequency Relay
82	DC Reclosing Relay
83	Automatic Selective Control or Transfer Relay
84	Operating Mechanism
85	Communications, Carrier or Pilot-Wire Relay
86	Lockout Relay
87	Differential Protective Relay
88	Auxiliary Motor or Motor Generator
89	Line Switch
90	Regulating Device
91	Voltage Directional Relay
92	Voltage and Power Directional Relay
93	Field Changing Contactor
94	Tripping or Trip-Free Relay
95	For specific applications where other numbers are not suitable
96	Busbar Trip Lockout relay
97	For specific applications where other numbers are not suitable
98	For specific applications where other numbers are not suitable
99	For specific applications where other numbers are not suitable
150	Earth Fault Indicator
AFD	Arc Flash Detector
CLK	Clock or Timing Source
DDR	Dynamic Disturbance Recorder
DFR	Digital Fault Recorder
ENV	Environmental Data
HIZ	High Impedance Fault Detector
HMI	Human Machine Interface
HST	Historian
LGC	Scheme Logic
MET	Substation Metering

Device No.	Description
PDC	Phasor Data Concentrator
PMU	Phasor Measurement Unit
PQM	Power Quality Monitor
RIO	Remote Input / Output Device
RTU	Remote Terminal Unit / Data Concentrator
SER	Sequence of Events Recorder
TCM	Trip Circuit Monitor

SUFFIXES & PREFIXES

Suffix letters or numbers may be used with device numbers. For example, the suffix “N” is used if the device is connected to a neutral wire, hence 59N is a relay used for protection against neutral displacement & suffixes X, Y, Z are used for auxiliary devices. Similarly, the "G" suffix is used to denote a "ground", hence "51G" is a time overcurrent ground relay. The "G" suffix can also mean "generator", hence "87G" is a generator differential relay while “87T” is a transformer differential relay. "F" can denote "field" on a generator or "fuse", as in the protective fuse for a transformer.

Suffix numbers are used to distinguish multiple "same" devices in the same equipment such as 51-1 & 51–2. Device numbers may be combined if the device provides multiple functions, such as instantaneous & inverse time overcurrent relay denoted as 50/51.

APPENDIX II

FULL LIST OF INFORMATION EXCHANGE REQUIREMENTS (SEE SECTION 9)

15.3 APPENDIX II: FULL LIST OF INFORMATION EXCHANGE REQUIREMENTS (SEE SECTION 9)

INFORMATION EXCHANGE REQUIREMENTS	PARAMETER	DESCRIPTION	RANGE (IF APPLICABLE)
NAMEPLATE INFORMATION‡ ('R')	Active power rating at unity power factor (nameplate active power rating)	Active power rating in watts at unity power factor.	
	Active power rating at specified over-excited power factor	Active power rating in watts at specified over-excited power factor.	
	Specified over-excited power factor	Over-excited power factor	
	Active power rating at specified under-excited power factor	Active power rating in watts at specified under-excited power factor.	
	Specified under-excited power factor	Under-excited power factor	
	Apparent power maximum rating	Maximum apparent power rating in voltamperes.	
	Normal operating performance category	Reactive power and voltage or power capability	
	Abnormal operating performance category	Voltage and frequency disturbance ride-through capability	
	Reactive power injected maximum rating	Maximum injected reactive power rating in vars.	
	Reactive power absorbed maximum rating	Maximum absorbed reactive power rating in vars.	
	Active power charge maximum rating	Maximum active power charge rating in watts.	
	Apparent power charge maximum rating	Maximum apparent power charge rating in voltamperes. May differ from the apparent power maximum rating.	
	AC voltage nominal rating	Nominal AC voltage rating in RMS volts	
	AC voltage maximum rating	Maximum AC voltage rating in RMS volts	
	AC voltage minimum rating	Minimum AC voltage rating in RMS volts	
	Supported control mode functions	Indication of support for each control mode function.	
	Reactive susceptance that remains connected to the Wire's Owner System in the cease to energize and trip state	Reactive susceptance that remains connected to Wire's Owner System in the cease to energize and trip state	
	Manufacturer	Manufacturer	
	Model	Model	
	Serial number	Serial number	
	Version	Version	

INFORMATION EXCHANGE REQUIREMENTS	PARAMETER	DESCRIPTION	RANGE (IF APPLICABLE)
MONITORING INFORMATION ('R')	Active Power	Active power in watts.	
	('R')	Reactive power in vars.	
	Voltage	Voltage(s) in volts. One parameter for single phase systems and three parameters for three phase systems.	
	Frequency	Frequency in Hertz.	
	Operational State	The current operational state of the DER. Minimum supported states are on and off but additional states may also be supported.	
	Connection Status	Power-connected status of the DER.	
	Alarm Status	Active alarm status.	
	Operational State of Charge	0% to 100% of operational energy storage capacity	
ENTER SERVICE PARAMETERS ('R/W')	Permit service	Able to enter or stay in service	Enabled/ Disabled†
	ES Maximum Voltage	Enter service maximum voltage	
	ES Minimum Voltage	Enter service minimum voltage	
	ES Maximum Frequency	Enter service maximum frequency	
	ES Minimum Frequency	Enter service minimum frequency	
	ES Delay	Enter service delay	0 – 600 s
	ES Randomized Delay	Enter service randomized delay	1 s – 1,000 s
	ES Ramp Rate	Enter service ramp rate	1 s – 1,000 s
VOLTAGE TRIP PARAMETERS ('R/W')	High Voltage shall trip curve points		
	Low Voltage shall trip curve points		
FREQUENCY TRIP PARAMETERS ('R/W')	HF Trip Curve Points	Over Frequency shall trip baseline and supplemental grades	
	LF Trip Curve Points	Under Frequency shall trip baseline and supplemental grades	
LIMIT MAXIMUM ACTIVE POWER PARAMETERS ('R/W')	Limit Active Power Enable	Enable mode	On / Off
	Active Power Control Requirements	Maximum active power setting	
MOMENTARY CESSATION PARAMETERS (NOT MANDATORY) ('R/W')	HV Momentary Cessation Curve Points	Over Voltage momentary cessation curve points Support for this setting is not mandatory	
	LV Momentary Cessation Curve Points	Under Voltage momentary cessation curve points Support for this setting is not mandatory	

COMMUNICATION PERFORMANCE REQUIREMENTS FOR DER INTERFACES ('R/W')	Availability of communication	When DER is operational	The local DER communication interface shall be active and responsive whenever the DER is operating and in a continuous operation region or mandatory operation region.
	Information read response time	≤ 30 s	The maximum amount of time to respond to read requests.
PCC VOLTAGE REGULATION VIA REACTIVE POWER CONTROL REQUIREMENTS			
ADJUSTABLE CONSTANT POWER FACTOR CONTROL FUNCTION PARAMETERS ('R/W')	Constant Power Factor Mode Enable	Enable constant power factor mode	On/Off
	Constant Power Factor	Constant Power Factor Setting	0-1
	Constant Power Factor Excitation	Constant power factor excitation setting	Over-excited or under-excited
INFORMATION EXCHANGE REQUIREMENTS	**PARAMETER**	**DESCRIPTION**	**RANGE (IF APPLICABLE)**
ADJUSTABLE CONSTANT REACTIVE POWER CONTROL FUNCTION PARAMETERS ('R/W')	Constant Reactive Power Mode Enable	Enable Constant Reactive Power mode	On/Off
	Constant Reactive Power	Constant Reactive Power setting	
REACTIVE POWER AS FUNCTION OF VOLTAGE CONTROL FUNCTION PARAMETERS ('R/W')	Voltage-Reactive Power Mode Enable	Enable Voltage-Reactive Power mode	On/Off
	VRef	Reference voltage	0.95–1.05 p.u. V nominal
	Autonomous VRef adjustment enable	Enable/disable autonomous VRef adjustment	On/Off
REACTIVE POWER AS FUNCTION OF VOLTAGE CONTROL FUNCTION PARAMETERS ('R/W')	VRef adjustment time constant	Adjustment range for VRef time constant	300 s to 5,000 s
	V/Q Curve Points	Voltage-reactive power curve points	
	Open Loop Response Time	Time to ramp up to 90% of the new reactive power target in response to the change in voltage	1–90 s
REACTIVE POWER AS FUNCTION OF ACTIVE POWER CONTROL FUNCTION PARAMETERS ('R/W')	Active power-reactive power Mode Enable	Enable active power-reactive power mode	On/Off
	P/Q Curve Points	Active power-reactive power curve points	

PCC VOLTAGE REGULATION VIA ACTIVE POWER CONTROL REQUIREMENTS			
DER ACTIVE POWER INJECTION RATE OF CHANGE CONTROL FUNCTION PARAMETERS (‘R/W’)	Initial rate during connection or reconnection to Distribution system	Default initial connect or re-connect rate is 2% of rated power per second	
	Average Rate of Change (W/second)	Average rate of change of active power (W/sec) adjustable from 1 to 100%	1 -100
ACTIVE POWER AS A FUNCTION OF VOLTAGE CONTROL FUNCTION PARAMETERS (‘R/W’)	Voltage-active power mode Enable	Enable constant power factor mode	On/Off
	V/P Curve points	Constant Power Factor Setting	
	Open Loop Response Time	Duration to ramp up to 90% of new active power output in response to a voltage change	0.5-60s
SYSTEM FREQUENCY SUPPORT VIA ACTIVE POWER CONTROL FUNCTION PARAMETERS (‘R/W’)	Over-frequency Droop DBOF	Deadband for over frequency conditions	
	Under-frequency Droop DBUF	Deadband for under frequency conditions	
	Over-frequency Droop KOF	Per unit frequency change during over frequency conditions which corresponds to a 1 per-unit power output change	
	Under-frequency Droop KUF	Per unit frequency change during under frequency conditions which corresponds to a 1 per-unit power output change	
	Open Loop Response Time	Duration for a step change in control input signal to cause a 90% output change in advance of overshoot	

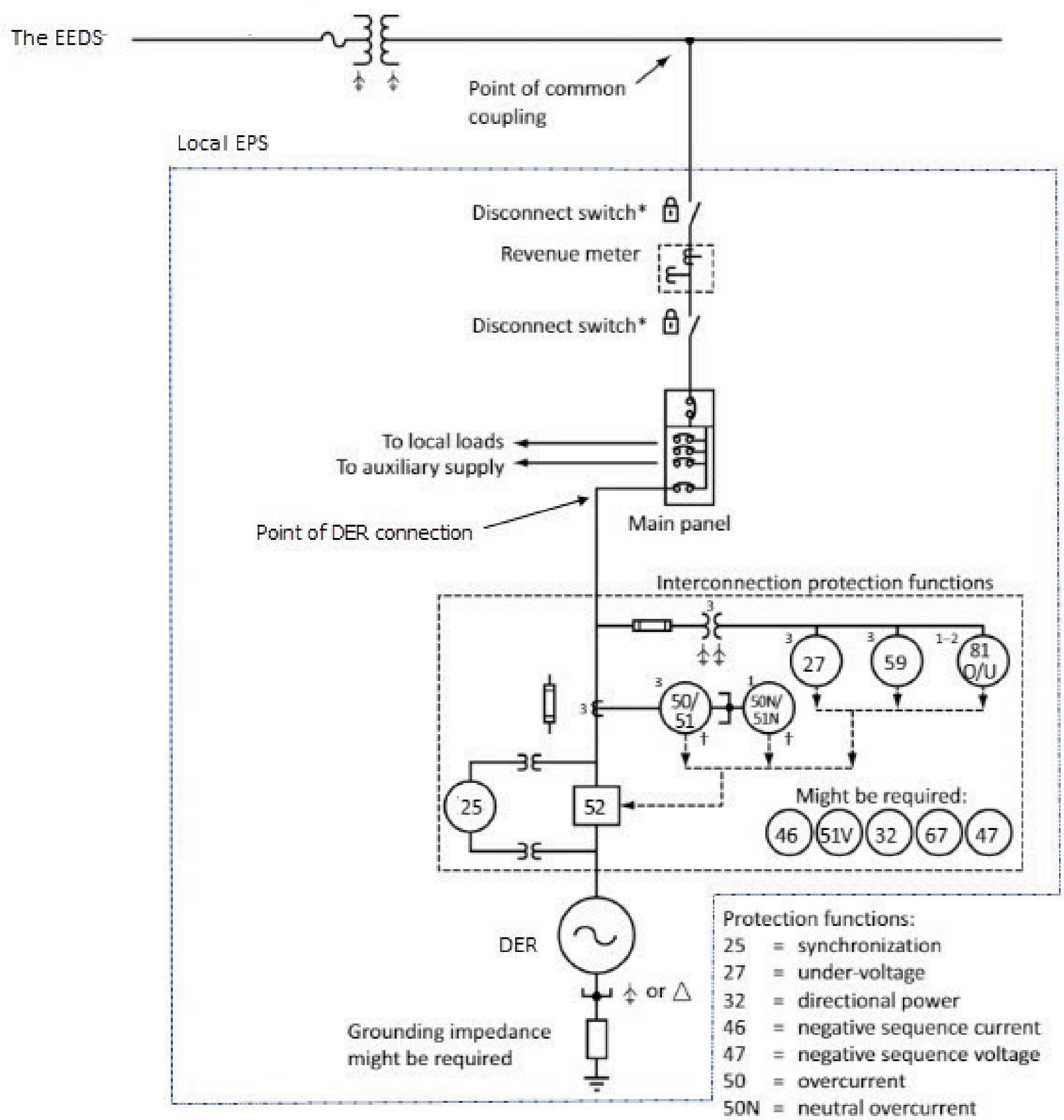
APPENDIX III

SINGLE-LINE DIAGRAMS OF TYPICAL DER INTERCONNECTIONS (SEE SECTION 12.2)

15.4 APPENDIX III: SINGLE-LINE DIAGRAMS OF TYPICAL DER INTERCONNECTIONS (SEE SECTION 12.2)

FIGURE 13

INTERCONNECTION OF A DER SYSTEM TO A LOW-VOLTAGE DISTRIBUTION SYSTEM WHERE THE DISTRIBUTION TRANSFORMER IS CONNECTED Yg-Yg



Protection functions:

- 25 = synchronization
- 27 = under-voltage
- 32 = directional power
- 46 = negative sequence current
- 47 = negative sequence voltage
- 50 = overcurrent
- 50N = neutral overcurrent
- 51 = overcurrent with delay
- 51N = neutral overcurrent with delay
- 51V = voltage restrained overcurrent
- 52 = AC circuit breaker
- 59 = over-voltage
- 67 = directional overcurrent
- 81O = over-frequency
- 81U = under-frequency

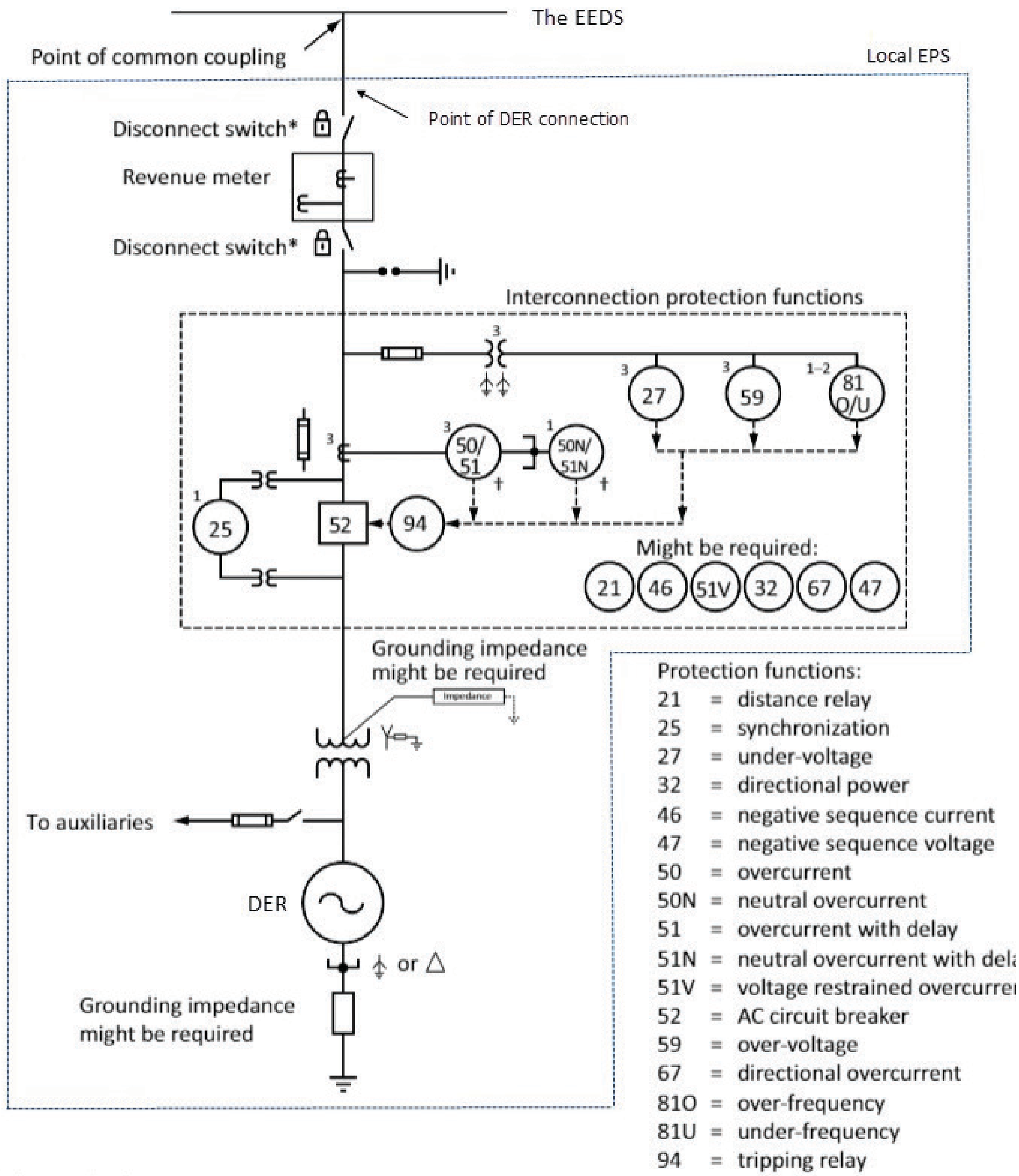
**Might be required*

†Overcurrent protection functions 50, 51, 50N, and 51N may be replaced by fuses, but might require other protection functions.

Note: *This Figure is informative. It is not to be used as a basis for installation or design.*

FIGURE 14

INTERCONNECTION OF A DER SYSTEM TO THE EEDS, WHERE THE INTERCONNECTION TRANSFORMER IS CONNECTED YG ON THE EEDS SIDE WITH SYNCHRONIZATION ON THE PRIMARY SIDE OF THE TRANSFORMER



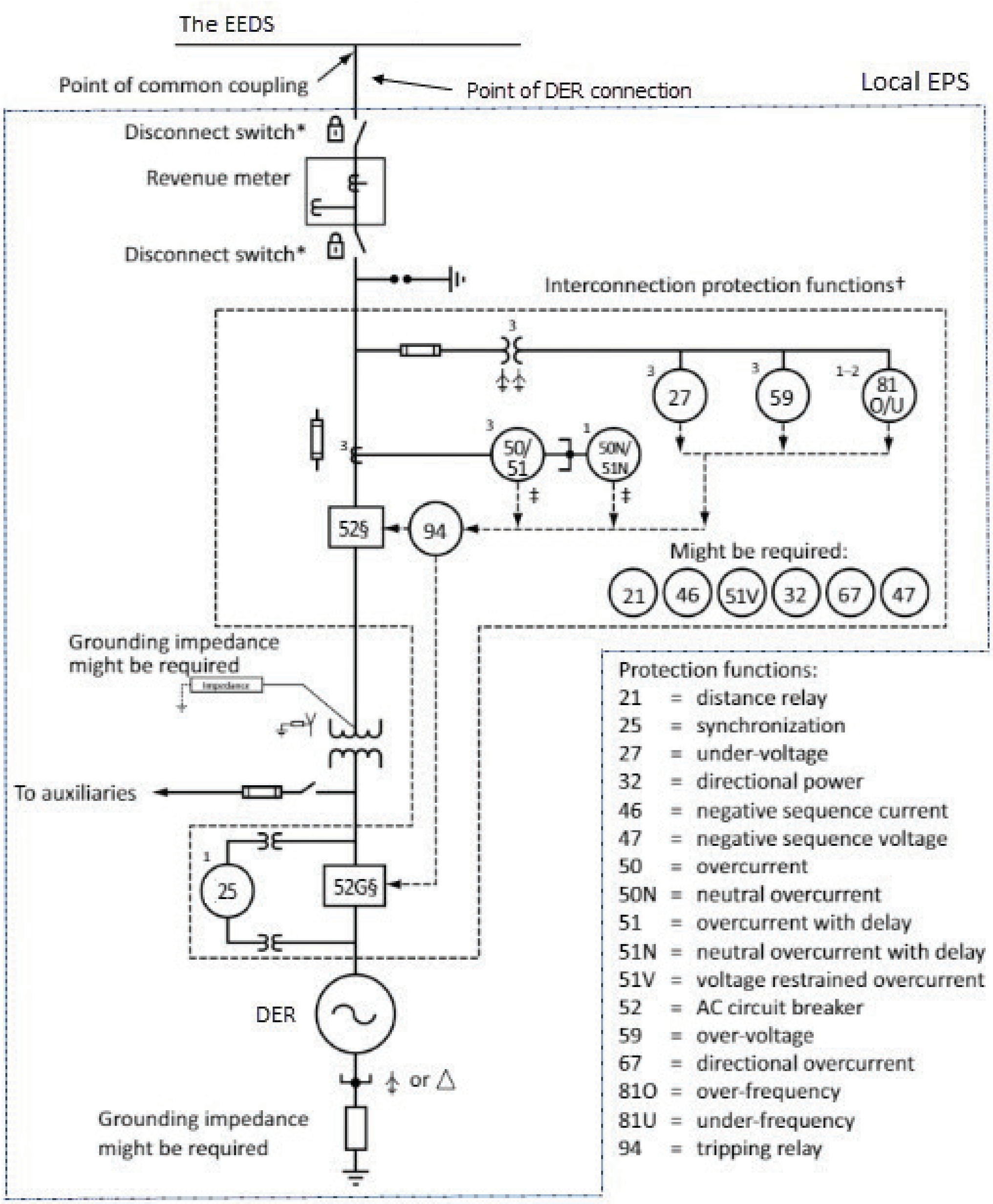
**Might be required*

†Overcurrent protection functions 50, 51, 50N, and 51N may be replaced by fuses, but might require other protection functions.

Note: *This Figure is informative. It is not to be used as a basis for installation or design.*

FIGURE 15

INTERCONNECTION OF A DER SYSTEM TO THE EEDS, WHERE THE INTERCONNECTION TRANSFORMER IS CONNECTED Yg ON THE EEDS SIDE WITH SYNCHRONIZATION ON THE SECONDARY SIDE OF THE TRANSFORMER



*Might be required

†The measurement for the interconnection protection functions can be done on the secondary side of the transformer (if grounded Y – grounded Y) with the approval of EDTI

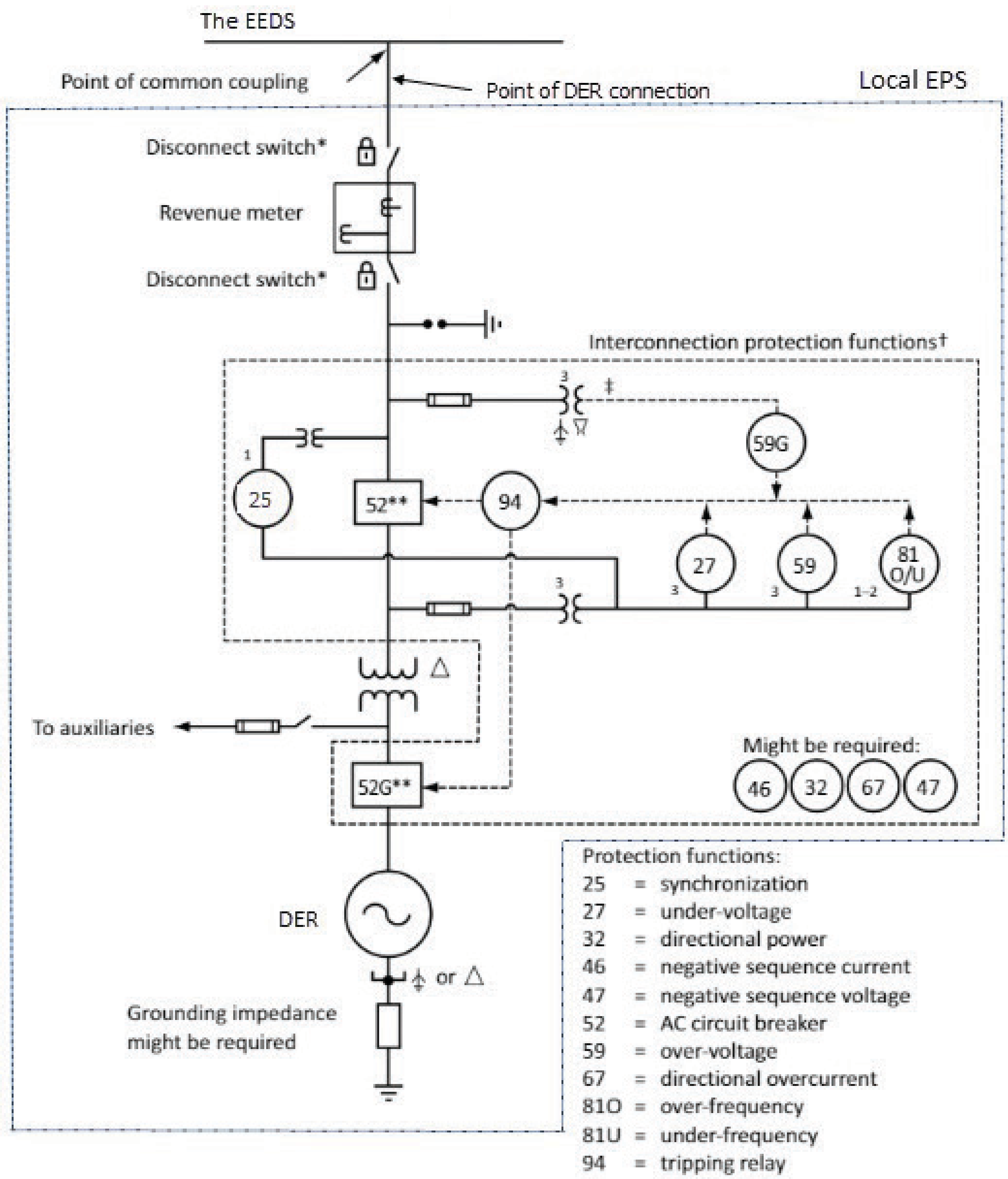
‡Overcurrent protection functions 50, 51, 50N, and 51N may be replaced by fuses, but might require other protection functions.

§The protection functions can operate the main current breaker (52) or DR breaker (52G) with the approval of the wires owner.

Note: This Figure is informative. It is not to be used as a basis for installation or design.

FIGURE 16

INTERCONNECTION OF A DER SYSTEM TO THE EEDS, WHERE THE INTERCONNECTION TRANSFORMER IS Δ CONNECTED ON THE EEDS SIDE WITH SYNCHRONIZATION ON THE PRIMARY SIDE OF THE TRANSFORMER



**Might be required*

†The measurement for the interconnection protection functions (except for 59G) can be done on the secondary side of the transformer with the approval of EDTI

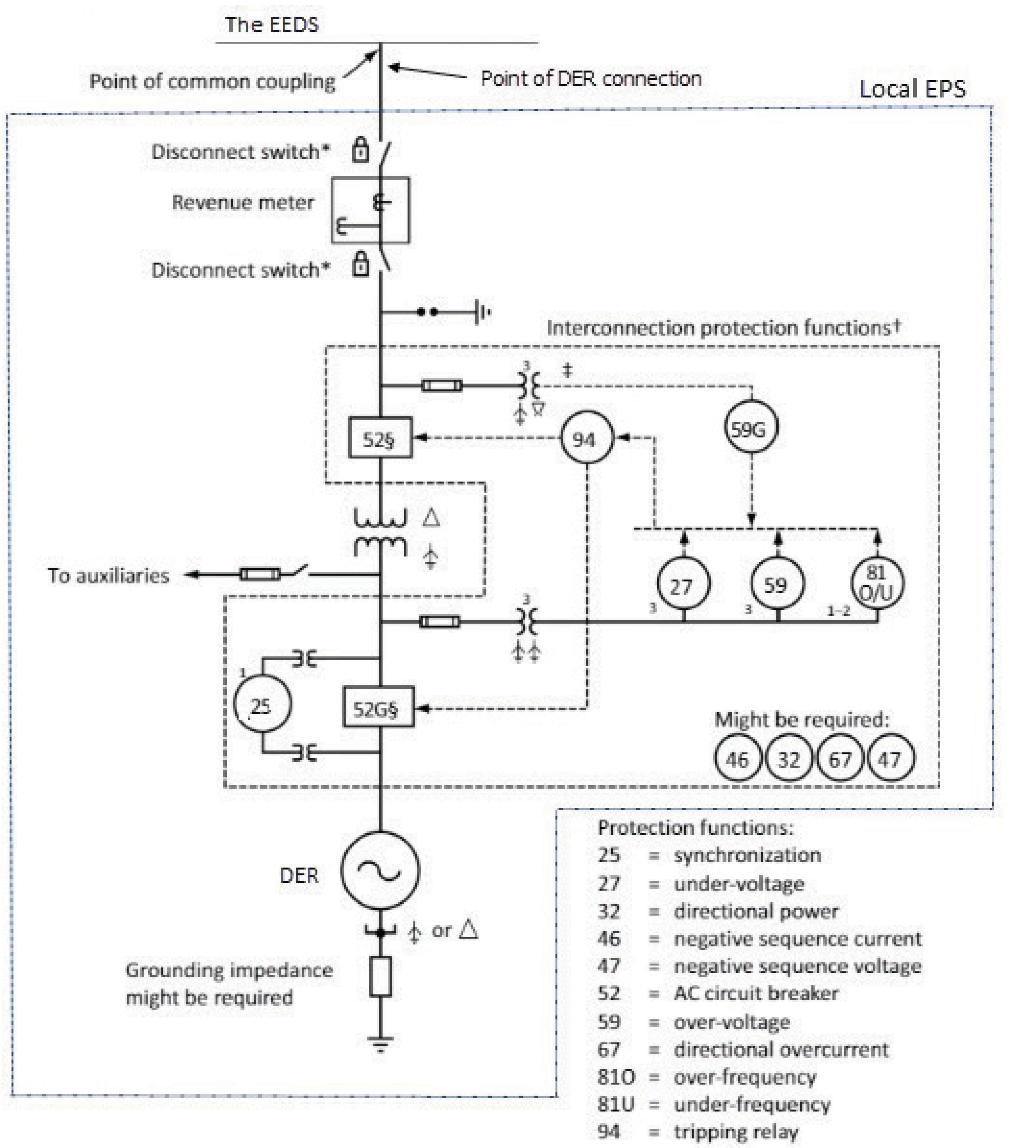
‡A Y-broken delta three-phase transformer with a 59G relay is required to detect single-phase line to ground faults on the EEDS

***The protection functions can operate the main current breaker (52) or* DER *breaker (52G) with the approval of* EDTI

Note: *This Figure is informative. It is not to be used as a basis for installation or design.*

FIGURE 17

INTERCONNECTION OF A DER SYSTEM TO THE EEDS, WHERE THE INTERCONNECTION TRANSFORMER IS Δ CONNECTED ON THE EEDS SIDE WITH SYNCHRONIZATION ON THE SECONDARY SIDE OF THE TRANSFORMER



**Might be required by the wires owner.*

†*The measurement for the interconnection protection functions (except for 59G) can be done on the secondary side of the transformer with the approval of* EDTI

‡*A Y-broken delta three-phase transformer with a 59G relay is required to detect single-phase line to ground faults on the EEDS*

§*The protection functions can operate the main current breaker (52) or* DER *breaker (52G) with the approval of* EDTI

Note: *This Figure is informative. It is not to be used as a basis for installation or design.*

APPENDIX VI

DETAILED COMMISSIONING TEST REQUIREMENTS (SEE SECTION 14.2.2.1)

15.5 APPENDIX VI: DETAILED COMMISSIONING TEST REQUIREMENTS (SEE SECTION 14.2.2.1)

SUBCLAUSE IN IEEE STD.		SUB											
SUBCLAUSE NUMBER	TITLE	DE1 – CONFIRM PERTINENT TYPE TEST AND PRODUCTION TEST REQUIREMENTS ARE MET	DE2 – CONFIRM WITH PROTECTION AND IMPACT STUDY	DE3 – SYSTEM DESIGN REVIEW	IE1 – VERIFY INSTALLATION MATCHES DESIGN EVALUATION	IE2 – VERIFY SYSTEM SETTINGS	IE3 – VERIFY STATE OF SYSTEM	CT1 – ON-OFF TEST	CT2 – REACTIVE POWER CAPABILITY AND CONTROL VERIFICATION	CT3 – VOLTAGE AND FREQUENCY TESTS	CT4 – POWER QUALITY TESTS	CT5 – INTER-OPERABILITY TESTS	CT6 - ISLANDING TEST
		8.3.1.1	8.3.1.2	8.3.1.3	8.3.2.1	8.3.2.2	8.3.2.3	8.3.3.1	8.3.3.2	8.3.3.3	8.3.3.4	8.3.3.5	8.3.3.6
4.2	Reference points of applicability	R	NR	R	R	NR	NR	NR	NR	NR	NR	NR	NR
4.3	Applicable voltages	R	NR	R	R	NR	NR	NR	NR	NR	NR	NR	NR
4.4	Measurement accuracy	R	NR	R	R	NR	NR	NR	NR	NR	NR	NR	NR
4.5	Cease-to-energize performance requirement	R	NR	R	NR	R	NR	D	NR	NR	NR	NR	NR
4.6.1	Capability to disable permit service	R	NR	R	R	R	NR	D	NR	NR	NR	NR	NR
4.6.2	Capability to limit active power	R	NR	R	R	NR	NR	D	NR	NR	NR	NR	NR
4.6.3	Execution of mode or parameter changes	R	NR	R	R	NR	NR	NR	D	NR	NR	NR	NR
4.7	Prioritization of DER responses and execution of mode or parameter changes	R	NR	R	R	NR	NR	D	D	D	NR	NR	NR
4.8	Isolation device	NR	NR	NR	R	NR	NR	D	NR	NR	NR	NR	NR
4.9	Inadvertent energization of the area EPS	R	NR	R	NR	NR	R	D	NR	NR	NR	NR	NR
4.10.2	Enter service criteria	R	NR	R	R	R	NR	D	NR	NR	NR	NR	NR
4.10.3	Performance during entering service	R	NR	R	NR	R	NR	D	NR	NR	NR	NR	NR
4.10.4	Synchronization	R	NR	R	R	NR	NR	D	NR	NR	NR	NR	NR
4.12	Integration with area EPS grounding	R	R	R	R	NR	NR	NR	NR	NR	NR	NR	NR
5.2	Reactive power capability of the DER	R	NR	R	R	NR	NR	NR	NR[a]	NR	NR	NR	NR
5.3.2	Constant power factor mode	R	NR	R	NR	R	NR	NR	R	NR	NR	NR	NR

SUBCLAUSE IN IEEE STD.		SUB											
SUBCLAUSE NUMBER	TITLE	DE1 – CONFIRM PERTINENT TYPE TEST AND PRODUCTION TEST REQUIREMENTS ARE MET	DE2 – CONFIRM WITH PROTECTION AND IMPACT STUDY	DE3 – SYSTEM DESIGN REVIEW	IE1 – VERIFY INSTALLATION MATCHES DESIGN EVALUATION	IE2 – VERIFY SYSTEM SETTINGS	IE3 – VERIFY STATE OF SYSTEM	CT1 – ON-OFF TEST	CT2 – REACTIVE POWER CAPABILITY AND CONTROL VERIFICATION	CT3 – VOLTAGE AND FREQUENCY TESTS	CT4 – POWER QUALITY TESTS	CT5 – INTER-OPERABILITY TESTS	CT6 - ISLANDING TEST
		8.3.1.1	8.3.1.2	8.3.1.3	8.3.2.1	8.3.2.2	8.3.2.3	8.3.3.1	8.3.3.2	8.3.3.3	8.3.3.4	8.3.3.5	8.3.3.6
5.3.3	Voltage-reactive power (volt-var) mode	R	NR	R	NR	R	NR	NR	R	NR	NR	NR	NR
5.3.4	Active power-reactive power (watt-var or P-Q) mode	R	NR	R	NR	R	NR	NR	R	NR	NR	NR	NR
5.3.5	Constant reactive power mode	R	NR	R	NR	R	NR	NR	R	NR	NR	NR	NR
5.4.2	Voltage-active power (volt-watt) mode	R	NR	R	NR	R	NR	NR	R	NR	NR	NR	NR
6.2	Area EPS faults and open phase conditions	R	R	R	NR	R	NR	NR[a]	NR	NR	NR	NR	NR[b]
6.3	Area EPS reclosing coordination	R	R	R	NR	NR	NR	D	NR	NR	NR	NR	D
6.4.1	Mandatory voltage tripping requirements	R	R	R	NR	R	NR	NR	NR	NR[b]	NR	NR	NR
6.4.2.1	General requirements and exceptions	R	NR	R	NR	R	NR	NR	NR	D	NR	NR	NR
6.4.2.2	Voltage disturbances within continuous operation region	R	NR	R	NR	NR	NR	NR	NR	D	NR	NR	NR
6.4.2.3.2	Low-voltage ride-through capability	R	NR	R	NR	NR	NR	NR	NR	D	NR	NR	NR
6.4.2.3.3	Low-voltage ride-through performance	R	NR	R	NR	NR	NR	NR	NR	D	NR	NR	NR
6.4.2.4.2	High-voltage ride-through capability	R	NR	R	NR	NR	NR	NR	NR	D	NR	NR	NR
6.4.2.4.3	High-voltage ride-through performance	R	NR	R	R	NR	NR	NR	NR	D	NR	NR	NR
6.4.2.4.5	Ride-through of consecutive voltage disturbances	R	NR	R	R	NR	NR	NR	NR	D	NR	NR	NR
6.4.2.6.1	Dynamic voltage support capability	R	NR	R	R	NR	NR	NR	NR	D	NR	NR	NR
6.4.2.6.2	Dynamic voltage support performance	R	NR	R	R	NR	NR	NR	NR	D	NR	NR	NR
6.4.2.7.1	Restore output without dynamic voltage support	R	NR	R	R	R	NR	NR	NR	D	NR	NR	NR
6.4.2.7.2	Restore output with dynamic voltage support	R	NR	R	R	R	NR	NR	NR	D	NR	NR	NR

SUBCLAUSE IN IEEE STD.		SUB											
SUBCLAUSE NUMBER	TITLE	DE1 – CONFIRM PERTINENT TYPE TEST AND PRODUCTION TEST REQUIREMENTS ARE MET	DE2 – CONFIRM WITH PROTECTION AND IMPACT STUDY	DE3 – SYSTEM DESIGN REVIEW	IE1 – VERIFY INSTALLATION MATCHES DESIGN EVALUATION	IE2 – VERIFY SYSTEM SETTINGS	IE3 – VERIFY STATE OF SYSTEM	CT1 – ON-OFF TEST	CT2 – REACTIVE POWER CAPABILITY AND CONTROL VERIFICATION	CT3 – VOLTAGE AND FREQUENCY TESTS	CT4 – POWER QUALITY TESTS	CT5 – INTER-OPERABILITY TESTS	CT6 - ISLANDING TEST
		8.3.1.1	8.3.1.2	8.3.1.3	8.3.2.1	8.3.2.2	8.3.2.3	8.3.3.1	8.3.3.2	8.3.3.3	8.3.3.4	8.3.3.5	8.3.3.6
6.4.2.7.3	Transition between performance operating regions for Category III DER	R	NR	R	R	R	NR	NR	NR	D	NR	NR	NR
6.5.1	Mandatory frequency tripping requirements	R	R	R	NR	R	NR	NR	NR	D	NR	NR	NR
6.6	Return to service after trip	R	NR	R	R	R	NR	D	NR	D	NR	NR	NR
7.1	Limitation of dc injection	R	NR	R	R	NR	NR	NR	NR	NR	NR[b]	NR	NR
7.2.2	Rapid voltage changes (RVC)	NR	R	R	NR	NR	NR	NR	NR	NR	D	NR	NR
7.2.3	Flicker	NR	R	R	NR	NR	NR	NR	NR	NR	D	NR	NR
7.3	Limitation of current distortion	R	NR	R	R	NR	NR	NR	NR	NR	D	NR	NR
7.4	Limitation of overvoltage contribution	R	R	R	R	NR	NR	NR	NR	NR	D	NR	NR
8.1	Unintentional islanding	R	R	R	R	R	NR	NR	NR	NR	NR	NR	R
8.1.2	Conditional extended clearing time	NR	R	R	R	NR	NR	NR	NR	NR	NR	NR	R
8.1.3	Area EPS with automatic reclosing	NR	R	R	R	NR	NR	NR	NR	NR	NR	NR	R
8.2.2	Scheduled intentional islands	NR	R	R	R	NR	NR	NR	NR	NR	NR	NR	R
8.2.3	Unscheduled intentional islands	NR	R	R	R	NR	NR	NR	NR	NR	NR	NR	R
8.2.4	Conditions for unscheduled transition to intentional island	NR	R	R	R	NR	NR	NR	NR	NR	NR	NR	R
8.2.5	Transition of an intentional island from the area EPS	NR	R	R	R	NR	NR	NR	NR	NR	NR	NR	R
8.2.6	Reconnection of an intentional island to the area EPS	NR	R	R	R	NR	NR	NR	NR	NR	NR	NR	R
8.2.7	Adjustments to DER settings	NR	R	R	R	R	NR	NR	NR	NR	NR	NR	R
8.2.8	DER categories for microgrid islands	NR	R	R	R	NR	NR	NR	NR	NR	NR	NR	R

SUBCLAUSE IN IEEE STD.		SUB											
SUBCLAUSE NUMBER	TITLE	DE1 – CONFIRM PERTINENT TYPE TEST AND PRODUCTION TEST REQUIREMENTS ARE MET	DE2 – CONFIRM WITH PROTECTION AND IMPACT STUDY	DE3 – SYSTEM DESIGN REVIEW	IE1 – VERIFY INSTALLATION MATCHES DESIGN EVALUATION	IE2 – VERIFY SYSTEM SETTINGS	IE3 – VERIFY STATE OF SYSTEM	CT1 – ON-OFF TEST	CT2 – REACTIVE POWER CAPABILITY AND CONTROL VERIFICATION	CT3 – VOLTAGE AND FREQUENCY TESTS	CT4 – POWER QUALITY TESTS	CT5 – INTER-OPERABILITY TESTS	CT6 - ISLANDING TEST
		8.3.1.1	8.3.1.2	8.3.1.3	8.3.2.1	8.3.2.2	8.3.2.3	8.3.3.1	8.3.3.2	8.3.3.3	8.3.3.4	8.3.3.5	8.3.3.6
9.2	Distribution secondary grid networks	NR	R	R	R	R	R	D	NR	NR	NR	NR	D
9.3	Distribution secondary spot networks	NR	R	R	R	R	R	D	NR	NR	NR	NR	D
10.3	Nameplate information	R	NR	R	R	R	NR	NR	NR	NR	NR	D	NR
10.4	Configuration information	R	NR	R	R	R	NR	NR	NR	NR	NR	D	NR
10.5	Monitoring information	R	NR	R	R	R	NR	NR	NR	NR	NR	D	NR
10.6.2	Constant power factor mode parameters	R	NR	R	R	R	NR	NR	NR	NR	NR	D	NR
10.6.3	Voltage-reactive power mode parameters	R	NR	R	R	R	NR	NR	NR	NR	NR	D	NR
10.6.4	Active power–reactive power mode parameters	R	NR	R	R	R	NR	NR	NR	NR	NR	D	NR
10.6.5	Constant reactive power mode parameters	R	NR	R	R	R	NR	NR	NR	NR	NR	D	NR
10.6.6	Voltage–active power mode parameters	R	NR	R	R	R	NR	NR	NR	NR	NR	D	NR
10.6.7	Voltage trip and momentary cessation parameters	R	NR	R	R	R	NR	NR	NR	NR	NR	D	NR
10.6.8	Frequency trip parameters	R	NR	R	R	R	NR	NR	NR	NR	NR	D	NR
10.6.9	Frequency droop parameters	R	NR	R	R	R	NR	NR	NR	NR	NR	D	NR
10.6.10	Enter service	R	NR	R	R	R	NR	NR	NR	NR	NR	D	NR
10.6.11	Cease-to-energize and trip	NR	NR	NR	NR	R	NR	NR	NR	NR	NR	D	NR
10.6.12	Limit maximum active power	R	NR	R	R	R	NR	NR	NR	NR	NR	D	NR
10.7	Communication protocol requirements	R	NR	R	R	NR	NR	NR	NR	NR	NR	D	NR
10.8	Communication performance requirements	R	NR	R	R	NR	NR	NR	NR	NR	NR	D	NR

Legend: R = required evaluation or test, D = test dependent on design evaluation, NR = no requirement, Shaded = no requirement in IEEE Std. 1547-2018.