

IEEE Standard 1547

The criteria and requirements in this document are applicable to all distributed resource technologies, with aggregate capacity of **10 MVA or less at the PCC**, interconnected to EPSs at typical primary and/or secondary distribution voltages. Installation of DR on **radial** primary and secondary **distribution systems is the main emphasis of this standard**, although installation of DR on primary and secondary **network distribution systems is considered**. This standard is written considering that the DR is a 60 Hz source.

What is a Network Distribution System ?

4.1.1 Voltage regulation

The DR shall not actively regulate the voltage at the PCC. The DR shall not cause the Area EPS service voltage at other Local EPSs to go outside the requirements of ANSI C84.1-1995, Range A.

4.1.2 Integration with Area EPS grounding

The grounding scheme of the DR interconnection shall not cause overvoltages that exceed the rating of the equipment connected to the Area EPS and shall not disrupt the coordination of the ground fault protection on the Area EPS.

4.1.3 Synchronization

The DR unit shall parallel with the Area EPS without causing a voltage fluctuation at the PCC greater than $\pm 5\%$ of the prevailing voltage level of the Area EPS at the PCC, and meet the flicker requirements of 4.3.2.

4.1.4.1 Distribution secondary grid networks

This topic is under consideration for future revisions of this standard.

4.1.4.2 Distribution secondary spot networks⁸

Network protectors shall not be used to separate, switch, serve as breaker failure backup or in any manner isolate a network or network primary feeder to which DR is connected from the remainder of the Area EPS, unless the protectors are rated and tested per applicable standards for such an application.⁹

Any DR installation connected to a spot network shall not cause operation or prevent reclosing of any network protectors installed on the spot network. This coordination shall be accomplished without requiring any changes to prevailing network protector clearing time practices of the Area EPS.

Connection of the DR to the Area EPS is only permitted if the Area EPS network bus is already energized by more than 50% of the installed network protectors.

The DR output shall not cause any cycling of network protectors.

The network equipment loading and fault interrupting capacity shall not be exceeded with the addition of DR.

DR installations on a spot network, using an automatic transfer scheme in which load is transferred between the DR and the EPS in a momentary make-before-break operation, shall meet all the requirements of this clause regardless of the duration of paralleling.

4.1.5 Inadvertent energization of the Area EPS

The DR shall not energize the Area EPS when the Area EPS is de-energized.

4.1.6 Monitoring provisions

Each DR unit of 250 kVA or more or DR aggregate of 250 kVA or more at a single PCC shall have provisions for monitoring its connection status, real power output, reactive power output, and voltage at the point of DR connection.

4.1.7 Isolation device

When required by the Area EPS operating practices, a readily accessible, lockable, visible-break isolation device shall be located between the Area EPS and the DR unit.

4.1.8.1 Protection from electromagnetic interference

The interconnection system shall have the capability to withstand electromagnetic interference (EMI) environments in accordance with IEEE Std C37.90.2-1995. The influence of EMI shall not result in a change in state or misoperation of the interconnection system.

4.1.8.2 Surge withstand performance

The interconnection system shall have the capability to withstand voltage and current surges in accordance with the environments defined in IEEE Std C62.41.2-2002 or IEEE Std C37.90.1-2002 as applicable.

4.1.8.3 Paralleling device

The interconnection system paralleling-device shall be capable of withstanding 220% of the interconnection system rated voltage.

4.2 Response to Area EPS abnormal conditions¹⁰

Abnormal conditions can arise on the Area EPS that require a response from the connected DR. This response contributes to the safety of utility maintenance personnel and the general public, as well as the avoidance of damage to connected equipment, including the DR. All voltage and frequency parameters specified in these subclauses shall be met at the PCC, unless otherwise stated.

4.2.1 Area EPS faults

The DR unit shall cease to energize the Area EPS for faults on the Area EPS circuit to which it is connected.

4.2.2 Area EPS reclosing coordination

The DR shall cease to energize the Area EPS circuit to which it is connected prior to reclosure by the Area EPS.

4.2.3 Voltage

The protection functions of the interconnection system shall detect the effective (rms) or fundamental frequency value of each phase-to-phase voltage, except where the transformer connecting the Local EPS to the Area EPS is a grounded wye-wye configuration, or single-phase installation, the phase-to-neutral voltage shall be detected. When any voltage is in a range given in Table 1, the DR shall cease to energize the Area EPS within the clearing time as indicated. Clearing time is the time between the start of the abnormal condition and the DR ceasing to energize the Area EPS. For DR less than or equal to 30 kW in peak capacity, the voltage set points and clearing times shall be either fixed or field adjustable. For DR greater than 30 kW, the voltage set points shall be field adjustable.

The voltages shall be detected at either the PCC or the point of DR connection when any of the following conditions exist:

- a) The aggregate capacity of DR systems connected to a single PCC is less than or equal to 30 kW,
- b) The interconnection equipment is certified to pass a non-islanding test for the system to which it is to be connected,
- c) The aggregate DR capacity is less than 50% of the total Local EPS minimum annual integrated electrical demand for a 15 minute time period, and export of real or reactive power by the DR to the Area EPS is not permitted.

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The voltages shall be detected at either the PCC or the point of DR connection when any of the following conditions exist:

- a) The aggregate capacity of DR systems connected to a single PCC is less than or equal to 30 kW,
- b) The interconnection equipment is certified to pass a non-islanding test for the system to which it is to be connected,
- c) The aggregate DR capacity is less than 50% of the total Local EPS minimum annual integrated electrical demand for a 15 minute time period, and export of real or reactive power by the DR to the Area EPS is not permitted.

Table 1—Interconnection system response to abnormal voltages

<u>Voltage range</u> <u>(% of base voltage ^a)</u>	<u>Clearing time (ms) ^b</u>
$V < 50$	0.16
$50 < V < 88$	2.00
$110 < V < 120$	1.00
$V \sim 120$	0.16

^a Base voltages are the nominal system voltages stated in ANSI C84.1-1995, Table 1.

^b DR ~ 30 kW, maximum clearing times; DR > 30kW, default clearing times.

4.2.4 Frequency

When the system frequency is in a range given in Table 2, the DR shall cease to energize the Area EPS within the clearing time as indicated. Clearing time is the time between the start of the abnormal condition and the DR ceasing to energize the Area EPS. For DR less than or equal to 30 kW in peak capacity, the frequency set points and clearing times shall be either fixed or field adjustable.

For DR greater than 30 kW, the frequency set points shall be field adjustable.

Adjustable underfrequency trip settings shall be coordinated with Area EPS operations.

Table 2—Interconnection system response to abnormal frequencies

<u>DR size</u>	<u>Frequency range (HZ)</u>	<u>Clearing times ^a</u>
~ 30 kW	< 59.3	0.16
	> 60.5	0.16
>30 kW	< (59.8 – 57.0) Adjustable set point	Adjustable 0.16 - 300
	< 57.0	0.16

^a DR ~ 30 kW, maximum clearing times; DR > 30 kW, default clearing times.

4.2.5 Loss of synchronism

Loss of synchronism protection is not required except as necessary to meet 4.3.2.

4.2.6 Reconnection to Area EPS

After an Area EPS disturbance, no DR reconnection shall take place until the Area EPS voltage is within Range B of ANSI C84.1-1995, Table 1, and frequency range of 59.3 Hz to 60.5 Hz. The DR interconnection system shall include an adjustable delay (or a fixed delay of five minutes) that may delay reconnection for up to five minutes after the Area EPS steady-state voltage and frequency are restored to the ranges identified above.

4.3 Power quality

4.3.1 Limitation of dc injection

The DR and its interconnection system shall not inject dc current greater than 0.5% of the full rated output current at the point of DR connection.

4.3.2 Limitation of flicker induced by the DR

The DR shall not create objectionable flicker for other customers on the Area EPS.¹¹

¹¹ Flicker is considered objectionable when it either causes a modulation of the light level of lamps sufficient to be irritating to humans, or causes equipment misoperation. For guidance, refer to IEEE Std 519TM-1992 [B5], IEEE P1453TM [B10], IEC/TR3 61000-3-7 [B1], IEC 61000-4-15 [B2], IEC 61400-21 [B3].

4.3.3 Harmonics

When the DR is serving balanced linear loads, harmonic current injection into the Area EPS at the PCC shall not exceed the limits stated below in Table 3. The harmonic current injections shall be exclusive of any harmonic currents due to harmonic voltage distortion present in the Area EPS without the DR connected.

Table 3—Maximum harmonic current distortion in percent of current (I)^a

Individual harmonic order h (odd harmonics) ^b	H<11	11<h<17	17<h<23	23<h<35	35<h	Total Demand Distortion (TDD)
Percent (%)	4.0	2.0	1.5	0.6	0.3	5.0

a I = the greater of the Local EPS maximum load current integrated demand (15 or 30 minutes) without the DR unit, or the DR unit rated current capacity (transformed to the PCC when a transformer exists between the DR unit and the PCC).

b Even harmonics are limited to 25% of the odd harmonic limits above.

4.4 Islanding

4.4.1 Unintentional islanding

For an unintentional island in which the DR energizes a portion of the Area EPS through the PCC, the DR interconnection system shall detect the island and cease to energize the Area EPS within two seconds of the formation of an island.¹²

¹² **Some examples by which this requirement may be met are:**

1. The DR aggregate capacity is less than one-third of the minimum load of the Local EPS.
2. The DR is certified to pass an applicable non-islanding test.
3. The DR installation contains reverse or minimum power flow protection, sensed between the Point of DR Connection and the PCC, which will disconnect or isolate the DR if power flow from the Area EPS to the Local EPS reverses or falls below a set threshold.
4. The DR contains other non-islanding means, such as:
 - a) forced frequency or voltage shifting,
 - b) transfer trip, or
 - c) governor and excitation controls that maintain constant power and constant power factor.

4.4.2 Intentional islanding

This topic is under consideration for future revisions of this standard.

5. Interconnection test specifications and requirements

This clause provides the test requirements to demonstrate that the interconnection system meets the requirements of Clause 4. The applicable tests from this clause are required for all interconnection systems. The results of these tests shall be formally documented.

The stated test specifications and requirements are universally needed for interconnection of DR including synchronous machines, induction machines, or static power inverters/converters, and will be sufficient for most installations.¹³

5.1 Design test

This design test shall be performed as applicable to the specific interconnection system technology. The test shall be performed on a representative sample, either in the factory, at a testing laboratory, or on equipment in the field.¹⁴

13 Additional tests may be necessary for some limited situations.

14 The design test of 5.1 may be adopted as the testing basis for certification of interconnection systems.

5.2 Production tests

Each interconnection system shall be subjected to requirements of 5.1.1 and 5.1.2. Interconnection systems with adjustable set points shall be tested at a single set of set points as specified by the manufacturer. This test may be conducted as a factory test or may be performed as part of a commissioning test (see 5.4).

5.3 Interconnection installation evaluation

5.3.1 Grounding integration with Area EPS

A system design verification shall be made to ensure that the requirements of 4.1.2 have been met.

5.3.2 Isolation device

A system design verification shall be made to ensure that the requirements of 4.1.7 have been met.

5.3.3 Monitoring provisions

A system design verification shall be made to ensure that the provisions for monitoring are in accordance with 4.1.6.

5.3.4 Area EPS faults

A system design verification shall be made to ensure that the requirements of 4.2.1 have been met.

5.3.5 Area EPS reclosing coordination

A system design verification shall be made to verify the interconnection system is coordinated with the Area EPS reclosing practices in accordance with 4.2.2.

5.4 Commissioning tests

All commissioning tests shall be performed based on written test procedures.¹⁹ The following visual inspections shall be performed:

- A visual inspection shall be made to ensure that the grounding coordination requirement of 4.1.2 has been implemented.
- A visual inspection shall be made to confirm the presence of the isolation device if required by 4.1.7.

Initial commissioning tests shall be performed on the installed DR and interconnection system equipment prior to the initial parallel operation of the DR. The following tests are required:

- Operability test on the isolation device.
- Unintentional-islanding functionality as specified in 5.4.1.
- Cease to energize functionality as specified in 5.4.2.
- Any tests of 5.1 that have not been previously performed on a representative sample and formally documented.
- Any tests of 5.2 that have not been previously performed.

¹⁹ Test procedures are commonly provided by equipment manufacturer(s) or system integrator(s) and approved by the equipment owner and Area EPS operator.

The applicable tests of 5.1 shall be repeated when:

- Functional software or firmware changes have been made on the interconnection system.
- Any hardware component of the interconnection system has been modified in the field, or replaced or repaired with parts different from the tested configuration.

Subclauses 5.4.1 and 5.4.2, and the applicable tests of 5.2 shall be repeated if:

- Protection settings have been changed after factory testing.
- Protection functions have been adjusted after the initial commissioning process.

5.4.1 Unintentional islanding functionality test

5.4.1.1 Reverse-power or minimum power test

A reverse-power or minimum power function, if used to meet the requirements of 4.4.1, shall be tested using injection techniques or by adjusting the DR output and local loads to verify that the reverse power or minimum power function is met.

5.4.1.2 Non-islanding functionality test

For non-islanding interconnection systems, 5.4.2 satisfies this requirement.

5.4.1.3 Other unintentional islanding functionality tests

If tests in 5.4.1.1 and 5.4.1.2 are not applicable to the interconnection system, the interconnection system shall be tested in accordance with procedures provided by the manufacturer or system integrator.

5.4.2 Cease to energize functionality test

Check the cease to energize functionality by operating a load interrupting device and verify the equipment ceases to energize its output terminals and does not restart/reconnect for the required time delay. The test shall be performed on each phase individually. This test verifies conformance to the cease to energize requirement of 4.1.4, 4.2.1, 4.2.2, 4.2.3, 4.2.4, and 4.4.1.

5.5 Periodic interconnection tests

All interconnection-related protective functions and associated batteries shall be periodically tested at intervals specified by the manufacturer, system integrator, or the authority who has jurisdiction over the DR interconnection. Periodic test reports or a log for inspection shall be maintained.