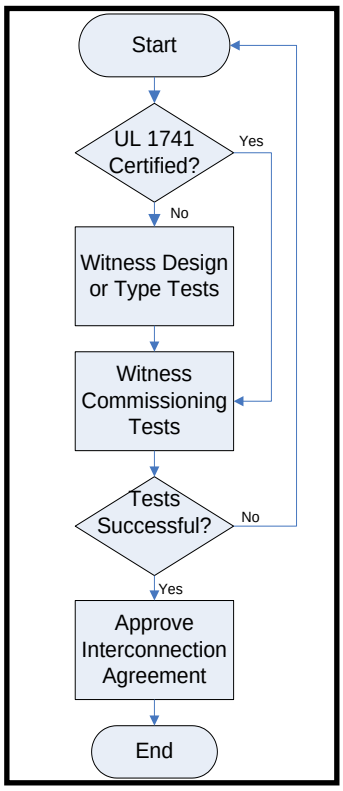
Distributed Generation Commissioning Test Requirements Guideline / Distributed Generation Witness Testing

Purpose

FirstEnergy is responsible for ensuring that reasonable precautions are taken when allowing customer-generators to interconnect to the distribution system. In addition to the overall project review and various system studies (feasibility studies system impact study, and facilities studies), larger distributed generation projects should be subject to FirstEnergy witnessing of the customer's commissioning tests.



This witnessing of customer commissioning tests shall be performed for all distributed generation projects greater than 1 MW for UL 1741[1] listed inverters, and greater than 500 kW for non-UL 1741 listed inverter/generators (see Commission Testing Flow Chart to the right).

Note: The Company has the option of witnessing the commissioning testing of any customer distributed generation project, regardless of size.

The witnessing of commissioning (and type tests) is the direct observation, by a Company representative, of testing performed by the customer (or the customer's representative).

The IEEE Standard 1547 family provides a set of standards for the interconnection of distributed generation resources, conformance testing, application guide, monitoring and control. The two standards of interest with regards to commissioning testing are IEEE Standard 1547a[2], which provides a standard for the interconnection of distributed resources and IEEE Standard 1547.1a[3], provides testing procedures for the Design (Type Tests), Production, Commissioning, and Periodic interconnection tests of distributed generation systems.

Information with a gray background represents requirements directly from IEEE Standards.

Text in italics is designed to offer "hints or guidance" on how particular testing steps may be performed. It is ultimately up to the customer's installer to design tests adequate to demonstrate compliance with the IEEE standards.

Design or Type Tests

Type Tests are performed on representative samples of the distributed generation interface equipment as part of the design and certification process. If an inverter is UL 1741 listed, or its equivalent, a Nationally Recognized Testing

[1] UL 1741 "Standard for Inverters, Converters, Controllers, and Interconnection System Equipment for use with Distributed Energy Resources"

[2] IEEE 1547a-2014 "IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems, Amendment 1," 3 Park Avenue, New York, NY 10016-5997, USA, IEEE.

[3] IEEE 1547.1a-2015 "IEEE Standard Conformance Test Procedures for Equipment Interconnecting Distributed Resources with Electric Power Systems, Amendment 1," 3 Park Avenue, New York, NY 10016-5997, USA, IEEE.

Laboratory (NRTL)[4] has performed these tests (as well as other tests) and is certifying that the units produced by the same manufacturer and to the same specification are in conformance with the testing requirements. This certification has been deemed sufficient to satisfy the Company's requirement for Type Testing.

Where the interface equipment is not UL 1741 Listed, the Company shall witness testing by the installer, sufficient to demonstrate the system installed should operate safely as installed. The IEEE Type Tests listed below, including an indication as to which tests need to be performed in the field for non UL 1741 Listed devices:

Witness Testing Required for Non-UL 1741 Listed Interconnection Equipment	
Required	**IEEE Type Test**
No	5.1 Temperature stability
Yes	5.2 Test for response to abnormal voltage conditions
Yes	5.3 Response to abnormal frequency conditions
Yes	5.4 Synchronization
No	5.5 Interconnection integrity
Yes	5.6 Limitation of dc injection for inverters without interconnection transformers
Yes	5.7 Unintentional islanding
Yes	5.8 Reverse power (for unintentional islanding)
Yes	5.9 Open phase
Yes	5.10 Reconnect following abnormal condition disconnect
Yes	5.11 Harmonics
Yes	5.12 Flicker

Test for response to abnormal voltage conditions

Testing for over-voltage and under-voltage shall be performed per the IEEE Standard, ensuring the interconnection equipment trips off-line within the Clearing Times listed in IEEE 1547a, Table 1 - Interconnection System Response to Abnormal Voltages.

[4] OSHA's Nationally Recognized Testing Laboratory (NRTL) Program: Recognizes private sector organizations to perform certification for certain products to ensure that they meet the requirements of both the construction and general industry OSHA electrical standards. For more information, see: https://www.osha.gov/dts/otpca/nrtl/

Table 1—Interconnection system default response to abnormal voltages

Default settings[a]		
Voltage range (% of base voltage[b])	Clearing time (s)	Clearing time: adjustable up to and including (s)
V < 45	0.16	0.16
45 ≤ V < 60	1	11
60 ≤ V < 88	2	21
110 < V < 120	1	13
V ≥ 120	0.16	0.16

[a] Under mutual agreement between the EPS and DR operators, other static or dynamic voltage and clearing time trip settings shall be permitted

[b] Base voltages are the nominal system voltages stated in ANSI C84.1-2011, Table 1.

Note:

- Clearing time is “start of incident to completed operation of device”

Tests for response to abnormal voltage conditions would typically be performed with a relay test set.

Response to abnormal frequency conditions

Testing for over-frequency and under-frequency shall be performed per the IEEE Standard, ensuring the interconnection equipment trips off-line within the Clearing Times listed in IEEE 1547a, Table 2 - Interconnection System Response to Abnormal Frequencies.

Table 2—Interconnection system default response to abnormal frequencies

	Default settings		Ranges of adjustability	
Function	Frequency (Hz)	Clearing time (s)	Frequency (Hz)	Clearing time (s) adjustable up to and including
UF1	< 57	0.16	56 – 60	10
UF2	< 59.5	2	56 – 60	300
OF1	> 60.5	2	60 – 64	300
OF2	> 62	0.16	60 – 64	10

Note:

- Clearing time is “start of incident to completed operation of device”

Tests for response to abnormal frequency conditions would typically be performed with a relay test set.

Synchronization
It would be difficult to build the test system, as described in IEEE 1547 a.1, for testing synchronization in the field, so testing for synchronization shall be performed by the disconnection and interconnection of the distributed generation for a total of five tests, monitoring for voltage fluctuations at the point of common coupling per IEEE 1547a, Clause 4.1.3.

> 4.1.3 Synchronization - The DR unit shall parallel with the Area EPS without causing a voltage fluctuation at the PCC greater than ±5% of the prevailing voltage level of the Area EPS at the PCC, and meet the flicker requirements of 4.3.2.

Notes:

- The distributed generation output should be close to full load during these tests.
- Interconnection of the distributed generation facilities during other parts of the type and commissioning tests may serve as synchronization testing attempts.
- When close to full load conditions are not possible, longer term monitoring of the distributed generation site may be necessary to ensure compliance.

Synchronization can be tested by monitoring voltage with a recording power quality meter at (or near) the PCC on the day of witness testing, and reviewing the data collected to determine if any of the five reconnections attempts violate the voltage fluctuations limits.

Where closet to full-load output is not available during testing, longer term monitoring with a power quality meter may be needed to demonstrate compliance.

Limitation of DC injection for inverters without interconnection transformers
FirstEnergy generally does not allow the installation of distributed generation facilities without interconnection transformers. In the event such installations are allowed, DC current measurements shall be made at the point of common coupling to ensure that the DC current injection is below the limits prescribed in IEEE 1547a, Clause 4.3.1.

Notes:

- Customer-owned interconnection transformers may block DC current injection.

> 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.

DC current injection can be tested by monitoring current with a suitable meter at (or near) the PCC on the day of witness testing, and reviewing the data collected to determine if the DC current violates the limits. Care with metering instrumentation

needs to be exercised to ensure that DC current is not blocked (i.e., by CT's). The configuration of customer transformers may block the injection of DC current, before such current reaches Company equipment and/or other customers.

Unintentional islanding

It would be difficult to build the test system, described in IEEE 1547.1a, for testing unintentional islanding in the field, so testing for unintentional islanding shall be performed by the opening of the customer feed at the point of common coupling, and ensuring that the distributed generation facility trips off line per the limits prescribed in IEEE 1547a, Clause 4.4.1.

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.

Additional information on the single-phase requirement of this test in provided in IEEE 1547a, Clause 5.4.2.

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.

Notes:

- For customers with three-phase systems, the unintentional islanding test shall be performed for each phase.
- The disconnection of the area electric power system shall be made on the primary side of any isolation transformers.

In most cases, testing for disconnection within two seconds does not need to be performed with a highly accurate timer. For remote timing cases, i.e., testing transfer trip, or de-energizing at a riser pole, remote from the inverter and/or relays being tested, simple voice cell-phone timing may be used … i.e., "I am opening on the count of 3 … one, two, three."

Reverse power (for unintentional islanding)
Where reverse-power flow is not allowed, testing shall be performed, ensuring the interconnection equipment trips off-line within two seconds for reverse power-flow conditions.

Notes:

- Other limits may be required for distributed generation projects connected with secondary network systems.

Tests for response to abnormal frequency conditions would typically be performed with a relay test set.

Open phase [5]
See unintentional islanding tests above for discussion and procedure.

IEEE Standard 1547.1a ~~[2005]~~ recognizes that single-phase outage occurrences are common, and the intent of this test is to demonstrate compliance with those common occurrences.

Reconnect following abnormal condition disconnect
Verify that the DG control system does not start its reconnection timer until abnormal conditions are removed (over/under voltage, over/under frequency, loss of phase, etc.). Validate that the reconnection timer is in compliance with IEEE 1547a Clause 4.2.6.

> 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.

If sufficient data is collected during the fore mentioned tests, additional on-off cycling of the DR may not be necessary to demonstrate reconnection following an abnormal event.

[5] IEEE 1547.1a [2005], Footnote 30, "This test is intended to demonstrate compliance with the individual phase requirement of the cease-to-energize functionality test of IEEE Std. 1547a. It is noted that loss of a phase is a common area EPS occurrence."

Harmonics

It would be difficult to build the test system, described in IEEE 1547.1a, for testing harmonic current injection into the area electrical power system. Therefore; harmonic testing shall be performed by measuring the distributed generation's current flow, ensuring that harmonic currents are in compliance with the limits specified in IEEE 1547a, Table 3 - Maximum Harmonic Current Distortion in Percent of Current

Notes:

- The distributed generation output should be close to full load during these tests.
- When close to full load conditions are not possible, longer term monitoring of the distributed generation site may be necessary to ensure compliance.

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.

Harmonic current injection can be tested by monitoring harmonic currents with a instantaneous or recording power quality meter at (or near) the PCC on the day of witness testing, and reviewing the data collected to determine if the harmonic injection limits are not violated. If insufficient data is connected during commissioning, a power quality meter with data logging functionality may need to be installed to validate compliance.

Flicker

There are no existing flicker type tests, as flicker is a function of both the changes in voltage, and the frequency at which those changes occur. Where flicker concerns are present, the Company may install a recording power quality meter at (or near) the PCC for the purposes of measuring, and later assessing flicker compliance.

4.3.2 Limitation of flicker induced by the DR

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

Where flicker concerns are present, the Company may install a suitable recording power quality meter at (or near) the PCC for flicker monitoring and later review of data

to determine if there are any flicker violations (see IEEE 519[6] for guidance). If violations are present, the Company will notify the Customer-Generator of such.

Commissioning test

Commissioning tests are performed by the Customer, after the distributed generation facilities are installed and ready for operation. Commissioning tests are designed to verify that the installation is complete, and meets the requirements of IEEE 1547a.

The inverter manufacturer or system integrator should have a published set of commissioning tests, for installers to follow, that ensure the proper setup and integration of distributed generation installations.

Notes:

- A commissioning test report shall be produced and available, even if the Company determines witness testing is not required.
- Commissioning testing is required for both UL 1741 Listed and non-Listed installations (IEEE 1547a Clause 5.4).
- For non-UL 1741 Listed projects the Type Testing, described above, may serve as some of the commissioning tests.

Witness Testing Required for All Interconnection Equipment	
Required	**IEEE Commissioning Test**
No	7.2 Verifications and inspections
Yes	7.3 Field-conducted type and production tests
Yes	7.4 Unintentional islanding functionality test
Yes	7.5 Cease-to-energize functionality test
Yes	7.6 Revised settings

Verifications and inspections

Visual inspection of the distributed generation interconnection facilities, note any concerns with regards to general workmanship and compliance of service entrance facilities with Company standards. This is not a NEC compliance inspection.

Before and during testing, Company witnesses shall perform:

- *a visual inspection of the equipment being tested, noting general workmanship,*
- *review of the one-line drawing*
- *review of applicable settings*
- *inspect the isolation and/or disconnect device(s)*

[6] IEEE 519-1992 “IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems,” 3 Park Avenue, New York, NY 10016-5997, USA, IEEE.

- *witnessing the customer/installer performing continuity checks, insulation checks, and wiring checks, as required and/or as recommended by the manufacturer/integrator*
- *witness the customer/installer checking rotation for three-phase systems*

Field-conducted type and production tests
See type tests above for non-UL 1741 Listed equipment. For field changes that may void the UL Listing (i.e., software changes, or certain configurations on some inverters) the type tests, detailed above, may be required.

If the Company has any concerns about the projects ability to operate safely, or pass any of the Design or Type Tests, listed above, the Company may request such tests, even for UL listed inverter-based projects.

Unintentional islanding functionality test
Testing shall be performed in accordance with the procedures provided by the manufacturer or system integrator. Where such procedures are not provided, follow the unintentional islanding testing, detailed above under Type Tests.

Cease-to-energize functionality test
Testing shall be performed in accordance with the procedures outlined in IEEE 1547.1a, Clause 7.5.1.

Revised settings
Where any changes are made to factory settings, or settings as already tested as part of this procedure, suitable tests shall be made to ensure the performance of the distributed generation interconnection facilities as prescribed by IEEE 1547a.