"Utility-Interactive":
What it Means, What Protection it Ensures

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Introduction

"Utility-Interactive" is a common term in the PV industry, but what does it actually mean? What does it guarantee, and what kind of protection does it ensure?

Section 100 of the NEC defines "Utility-Interactive" as, "An inverter intended for use in parallel with an electric utility to supply common loads that may deliver power to the utility." In other words, it describes the type of inverter that lets PV system owners export their excess power back to the utility.

PV inverters that are marked "Utility-Interactive" have undergone extensive testing to verify that they cannot energize the AC (utility) side unless they are actually connected to the utility. Utility-Interactive inverters are designed to export AC current only when they are actually connected to the grid and only when the grid is within specific voltage and frequency limits.

Basically, the "Utility-Interactive" designation ensures that the utility side of the inverter meets strict regulatory and safety requirements. It provides assurance that the inverter will not present a shock hazard should the utility circuit breaker be opened, even when DC input voltage is present. The inverter is a current source, not a voltage source, and as required by IEEE1547, the inverter must not regulate utility voltage.

Protective Boundary

A Utility-Interactive inverter forms a protective barrier between the DC (power source) side of the inverter and the AC (utility) interface. In the event of an out-of-tolerance utility connection, the inverter "ceases to energize," or shuts down, the AC (utility) side. Figure 1 is a general system diagram showing the line of demarcation between the DC power source and the utility.

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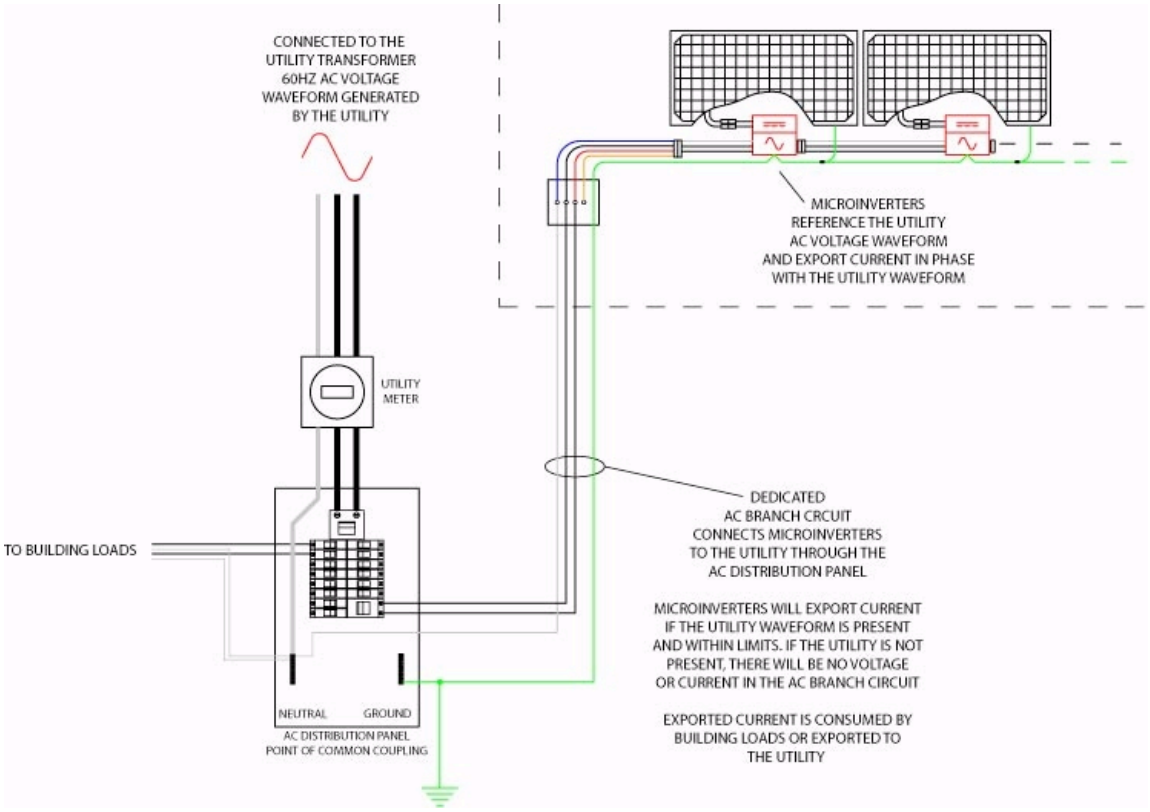

Figure 1

Testing Details

Before receiving the "Utility-Interactive Inverter" marking, an inverter must be listed to the UL1741 standard, which requires passing the tests described in Table 1 below. The tests include requirements outlined in IEEE1547, under which the manufacturer must state the accuracy of the time and amplitude characteristics of the "utility protective functions." The accuracy of the protective functions is tested during the UL1741 listing process.

	Test Title	Description	Comment
1	Utility low-voltage trip accuracy	With the utility frequency held at a nominal value, the voltage is lowered until the inverter "ceases to energize" the utility.	The normal low-voltage trip point is 88% of the nominal line-to-neutral voltage (Vnom).
2	Utility low-voltage trip time	Measures the time from when the utility voltage falls below 88% to when the inverter "ceases to energize."	Normal trip time is 2 seconds.

	Test Title	Description	Comment
3	Utility low-low trip accuracy	Same as #1	<50% Vnom
4	Utility low-low trip time	Same as #2	0.16 seconds
5	Utility high-voltage trip accuracy	With the utility frequency held at a nominal value, the voltage is raised until the inverter "ceases to energize" the utility.	The normal high-voltage trip point is 110% of Vnom.
6	Utility high-voltage trip time	Measures the time from when the utility voltage rises above 110% of Vnom to when the inverter "ceases to energize."	1 second
7	Utility high-high voltage trip accuracy	Same as #5	120% of Vnom
8	Utility high-high voltage trip time	Same as #6, but the voltage threshold is 120% of Vnom.	0.16 seconds
9	Utility low-frequency trip accuracy	With the utility voltage held at a nominal value, the frequency is lowered until the inverter "ceases to energize."	The low-trip limit is 59.3Hz nominal.
10	Utility low-frequency trip time	Measures the time from when the utility frequency falls below the low-frequency trip limit to when the inverter "ceases to energize."	0.16 seconds
11	Utility high-frequency trip accuracy	With the utility voltage held at nominal, the frequency is raised until the inverter "ceases to energize."	High-trip limit is 60.5Hz nominal.
12	Utility high-frequency trip time	Measures the time from when the utility frequency rises above the high-frequency trip limit to when the inverter "ceases to energize."	0.16 seconds
13	Utility loss-of-phase disconnection	While the inverter is exporting power, one phase is opened.	Inverter must "cease to energize" within 2 seconds.
14	Utility anti-islanding	Tested at 33%, 66%, and 100% of rated output power	Inverter must "cease to energize" within 2 seconds of creation of an island.
15	Output current harmonics	Current harmonics through the 40^{th} are quantified at 33%, 66%, and 100% of inverter rated output power.	Must be within limits specified in IEEE1547, 4.3.3, table 3.
16	Utility connection synchronization	Tests to ensure that the inverter does not connect out-of-phase with the utility.	Voltage, frequency, and phase must be within limits specified in IEEE1547, table 5.

	Test Title	Description	Comment
17	Utility reconnection timer	The inverter must wait for the grid to be within limits prior to reconnecting after a utility protective function trip.	5 minute timer is default. Can be adjusted per Utility request.
18	Limitation of DC injection into the utility	Injecting DC current into the utility can cause problems with equipment.	Must be less than 0.5% of inverter rated current.
19	Voltage surge withstand	Tested per the appropriate location category as defined in IEEE c62.41.	
20	Loss-of-control circuit	Tested as part of the "abnormals" tests in UL1741.	
21	EMI susceptibility	Tested per IEEE c37.90	
22	EMI emissions	Tested per FCC part 15	

Table 1

Only inverters that pass these tests and meet all other UL1741 requirements for an "inverter for use with distributed energy resources" can be marked "Utility-Interactive." The "Utility-Interactive" marking means that the inverter has met all utility-side safety requirements. Absence of the mark means that the inverter has not met all requirements for safe power export to the grid.

Other Benefits of Utility-Interactive

The "Utility-Interactive" inverter designation also insures protection of any power-consuming equipment connected to the utility. If the utility has a problem, the inverter will not damage appliances and electronic equipment, nor will it harm utility protection equipment such as protection relays, reverse power protectors, and reclosers. There is also a limited evaluation of product performance relative to unit rating label parameters.

Successful completion of the full suite of UL1741 tests by an inverter also ensures the safety of installation and maintenance personnel and system owners from physical harm due to fire or shock. If the utility is disconnected from the inverter by whatever means, the AC output terminals of a utility-interactive inverter are de-energized and completely safe to touch, with no danger of arcing or ignition.

Utility Reconnection

Utilities are typically interested in reconnection timer requirements. A Utility-Interactive inverter will not export power to the utility for 300 seconds (5 minutes) following an out-of-spec utility condition, and the utility must remain within acceptable limits during the full 300 seconds prior to the inverter recommencing exportation of power.

Table 2 summarizes the default acceptable limits for voltage and frequency. The inverter monitors the utility continually for out-of-spec conditions. If the utility exceeds these limits during the 300-second period, the timer is reset automatically. The 300-second timer and the voltage and frequency limits can be adjusted to different values with utility agreement. In fact, systems with a combined peak production capability of greater than 30kW must have adjustable set points.

Parameter	Low Limit	High Limit
Voltage	88% of Vnom	110% of Vnom
Frequency	59.3Hz	60.5Hz

Table 2

Production Testing

As part of the product listing process, the listing agency must inspect the product manufacturing facility at least four times per year. The inverter must be manufactured in compliance with a report that describes all components critical to maintaining product safety. Also, certain prescribed production tests must be performed on each unit prior to shipment from the factory. The tests verify the utility protective functions and integrity of the insulation system between DC input, AC output, and grounded metal components. Most manufacturers test well beyond basic safety requirements.

Summary

The "Utility-Interactive" marking provides significant assurance of inverter performance, utility compatibility, and safety. The label informs system designers, AHJs, system owners, and utility personnel that the product is appropriate for converting PV energy to electricity that can be exported safely to the utility grid.

The "Utility-Interactive" designation reduces the burden on system designers, plan checkers, inspectors, and utility personnel. Inverters that carry the marking can be connected safely to the utility to export AC power. Of course, installers must still verify that specific details of each installation are in compliance with national and local codes, as well as follow manufacturer's installation, operation, and maintenance instructions.