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INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Utility-interconnected photovoltaic inverters – Test procedure of islanding prevention measures

Onduleurs photovoltaïques interconnectés au réseau public – Procédure d'essai des mesures de prévention contre l'îlotage

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UTILITY-INTERCONNECTED PHOTOVOLTAIC INVERTERS – TEST PROCEDURE OF ISLANDING PREVENTION MEASURES

FOREWORD

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International Standard IEC 62116 has been prepared by IEC technical committee 82: Solar photovoltaic energy systems.

This second edition cancels and replaces the first edition issued in 2008 and constitutes a technical revision.

The main technical changes with regard to the previous edition are as follows:

	Previous edition	Present edition
Clause		
3.7	Real power	Active power
5.1		
5.4		
6.1 b)		
6.1 d)		
6.1 e)		
6.1 g)		
Table 1		
Table 6		
Table 7		
Table 9		
5.2	A PV array or PV array simulator (preferred) may be used. If the EUT can operate in utility-interconnected mode from a storage battery, a DC power source may be used in lieu of a battery as long as the DC power source is not the limiting device as far as the maximum EUT input current is concerned.	A DC power source, such as a PV array simulator, a PV array, or a current and voltage limited DC power supply with series resistance may be used. If the EUT can operate in utility-interconnected mode from a storage battery, a DC power source may be used in lieu of a battery as long as the DC power source shall not be the limiting device as far as the maximum EUT input current is concerned.
Table 5	EUT input voltage 90 %	EUT input voltage 75 %
	EUT input voltage 10 %	EUT input voltage 20 %
	EUT Trip Settings Manufacturer specified voltage and frequency trip settings	Voltage and frequency trip settings according to National standards and/or local code
Tables 6 & 7 (Heading)	Percent change in real load, reactive load from nominal	Percent change in active load, reactive load from nominal output power

The text of this standard is based on the following documents:

FDIS	Report on voting
82/813/FDIS	82/827/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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INTRODUCTION

Islanding is a condition in which a portion of an electric power grid, containing both load and generation, is isolated from the remainder of the electric power grid. This situation is one which electric power providers (utilities) regularly contend with. When an island is created purposely by the controlling utility – to isolate large sections of the utility grid, for example – it is called an intentional island. Conversely, an unintentional island can be created when a segment of the utility grid containing only customer-owned generation and load is isolated from the utility control.

Normally, the customer-owned generation is required to sense the absence of utility-controlled generation and cease energizing the grid. However, when the generation and load within the segment are well balanced prior to the isolation event, the utility is providing little power to the grid segment, thus making it difficult to detect when the isolation occurs. Damage can occur to customer equipment if the generation in the island, no longer under utility control, operates outside of normal voltage and frequency conditions. Customer and utility equipment can be damaged if the main grid recloses into the island out of synchronization. Energized lines within the island present a shock hazard to unsuspecting utility lineworkers who think the lines are dead.

The PV industry has pioneered the development of islanding detection and prevention measures. To satisfy the concerns of electric power providers, commercially-available utility-interconnected PV inverters have implemented a variety of islanding detection and prevention (also called anti-islanding) techniques. The industry has also developed a test procedure to demonstrate the efficacy of these anti-islanding techniques; that procedure is the subject of this document.

This standard provides a consensus test procedure to evaluate the efficacy of islanding prevention measures used by the power conditioner of utility-interconnected PV systems. Note that while this document specifically addresses inverters for photovoltaic systems, with some modifications the setup and procedure may also be used to evaluate inverters used with other generation sources or to evaluate separate anti-islanding devices intended for use in conjunction with PV inverters or other generation sources acting as or supplementing the anti-islanding feature of those sources.

Inverters and other devices meeting the requirements of this document can be considered non-islanding, meaning that under reasonable conditions, the device will detect island conditions and cease to energize the public electric power grid.

UTILITY-INTERCONNECTED PHOTOVOLTAIC INVERTERS – TEST PROCEDURE OF ISLANDING PREVENTION MEASURES

1 Scope

The purpose of this International Standard is to provide a test procedure to evaluate the performance of islanding prevention measures used with utility-interconnected PV systems.

This standard describes a guideline for testing the performance of automatic islanding prevention measures installed in or with single or multi-phase utility interactive PV inverters connected to the utility grid. The test procedure and criteria described are minimum requirements that will allow repeatability. Additional requirements or more stringent criteria may be specified if demonstrable risk can be shown. Inverters and other devices meeting the requirements of this standard are considered non-islanding as defined in IEC 61727.

This standard may be applied to other types of utility-interconnected systems (e.g. inverter-based microturbine and fuel cells, induction and synchronous machines). However, technical review may be necessary for other than inverter-based PV systems.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC/TS 61836, *Solar photovoltaic energy systems – Terms, definitions and symbols*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 61836 as well as the following apply.

3.1
PV array simulator
DC power source used to simulate PV array output

3.2
EUT
equipment under test
inverter or anti-islanding device on which these tests are performed

Note 1 to entry: This note applies to the French language only.

3.3
MPPT
maximum power point tracking
PV array control strategy used to maximize the output of the system under the prevailing conditions

Note 1 to entry: This note applies to the French language only.

3.4
non-islanding inverter
inverter that will cease to energize a utility distribution system that is out of the nominal operation specifications for voltage and/or frequency

[SOURCE: IEC 61727:2004, 3.8.1]

3.5
island
state in which a portion of the electric utility grid, containing load and generation, continues to operate isolated from the rest of the grid

Note 1 to entry: The generation and loads may be any combination of customer-owned and utility-owned.

3.6
intentional island
island that is intentionally created, usually to restore or maintain power to a section of the utility grid affected by a fault

Note 1 to entry: The generation and loads may be any combination of customer-owned and utility-owned, but there is an implicit or explicit agreement between the controlling utility and the operators of customer-owned generation for this situation.

3.7
quality factor
Q_f
a measure of the strength of resonance of the islanding test load

Note 1 to entry: In a parallel resonant circuit, such as a load on a power system

$$Q_f = R\sqrt{\frac{C}{L}}$$

where

Q_f is quality factor

R is effective load resistance

C is reactive load capacitance (including shunt capacitors)

L is reactive load inductance

With C and L tuned to the power system fundamental frequency, Q_f for the resonant circuit drawing active power, P, reactive powers Q_L, for inductive load and Q_C for capacitive load, Q_f can be determined by

$$Q_f = (1/P)\sqrt{|Q_L| \cdot |Q_C|}$$

where

P is active power, in W

Q_L is inductive load, in VAr_L

Q_C is capacitive load, in VAr_C

3.8
run-on time
t_R
amount of time that an unintentional island condition exists, calculated as the interval between the opening of the switch S1 (Figure 1) and the cessation of EUT output current

3.9
stopping signal
signal provided by the inverter indicating it has ceased energizing its utility grid-connected output terminals

SEE: Annex C.

3.10
unintentional island
islanding condition in which the generation within the island that is supposed to cease energizing the utility grid instead continues to energize the utility grid

4 Testing circuit

The testing circuit shown in Figure 1 shall be employed. Similar circuits shall be used for three-phase output.

Parameters to be measured are shown in Table 1 and Figure 1. Parameters to be recorded in the test report are discussed in Clause 7.

Table 1 – Parameters to be measured in real time

Parameter	Symbol	Units
EUT DC input [a, b]		
DC voltage	V_{DC}	V
DC current	I_{DC}	A
DC power	P_{DC}	W
Irradiance [c]	G	W/m^2
EUT AC output		
AC voltage [b, d, e]	V_{EUT}	V
AC current [b, d, e]	I_{EUT}	A
Active power [b]	P_{EUT}	W
Reactive power [b]	Q_{EUT}	VAr
Voltage waveform [d, e, f, g]		
Current waveform [d, e, f, g]		
EUT (relay) output control signal [d]		
Run-on time	t_R	s
Stopping signal [h]	SS	--
Test load [b]		
Resistive load current	I_R	A
Inductive load current	I_L	A
Capacitive load current	I_C	A
AC (utility) power source		
Utility active power [i]	P_{AC}	W
Utility reactive power [i]	Q_{AC}	VAr
Utility current [i]	I_{AC}	A

[a] If applicable.

[b] Record values measured before switch S1 is opened.

[c] Recorded when the test is carried out using a PV array. Pyranometer should be fast response silicon-type not thermopile-type.

[d] The response time of voltage and current transducer shall be suitable for the sampling rate used.

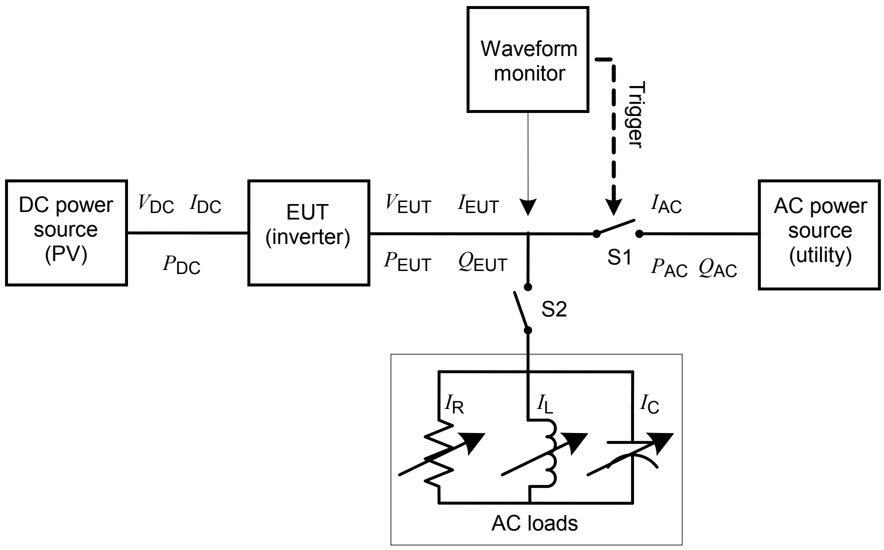
[e] The waveform, AC voltage and current shall be measured on all phases.

[f] The waveform data shall be recorded from the beginning of the islanding test until the EUT ceases output. The measurement of time shall have an accuracy and resolution of better than 1 ms.

[g] When the waveform is recorded, the synchronizing signal of the S1 opening and stopping signal may be simultaneously recorded.

[h] If available from the EUT.

[i] Signal shall be filtered as necessary to provide fundamental (50 Hz or 60 Hz) frequency value. Fundamental values will ignore incidental harmonics, caused by utility voltage distortion, absorbed by the load and EUT filtering capacitors.



IEC 1567/08

Figure 1 – Test circuit for islanding detection function in a power conditioner (inverter)

5 Testing equipment

5.1 Measuring instruments

Waveform observation shall be measured by a device with memory function, for example, a storage or digital oscilloscope or a high speed data acquisition system. The waveform measurement/capture device shall be able to record the waveform from the beginning of the islanding test until the EUT ceases to energize the island. For multi-phase EUT, all phases shall be monitored. A waveform monitor designed to detect and calculate the run-on time may be used.

For multi-phase EUT, the test and measurement equipment shall record each phase current and each phase-to-neutral or phase-to-phase voltage, as appropriate, to determine fundamental frequency active and reactive power flow over the duration of the test. A sampling rate of 10 kHz or higher is recommended. The minimum measurement accuracy shall be 1 % or less of rated EUT nominal output voltage and 1 % or less of rated EUT output current. Current, active power, and reactive power measurements through switch S1 used to determine the circuit balance conditions shall report the fundamental (50 Hz or 60 Hz) component.

5.2 DC power source

5.2.1 General

A DC power source, such as a PV array simulator, a PV array, or a current and voltage limited DC power supply with series resistance may be used.

If the EUT can operate in utility-interconnected mode from a storage battery, a DC power source may be used in lieu of a battery as long as the DC power source shall not be the limiting device as far as the maximum EUT input current is concerned.

The DC power source shall provide voltage and current necessary to meet the testing requirements described in Clause 6.

5.2.2 PV array simulator

A unit intended to be energized directly from a photovoltaic source shall be energized from a supply that simulates the current-voltage characteristics and time response of a photovoltaic array. The tests shall be conducted at the input voltage defined in Table 2 below, and the current shall be limited to 1,5 times the rated photovoltaic input current, except when specified otherwise by the test requirements.

A PV array simulator is recommended, however, any type of power source may be used if it does not influence the test results.

Table 2 – Specification of array simulator (test conditions)

Items [a]	Conditions
Output power	Sufficient to provide maximum EUT output power and other levels specified by test conditions of Table 5.
Response speed [b]	The response time of a simulator to a step in output voltage, due to a 5 % load change, should result in a settling of the output current to within 10 % of its final value in less than 1 ms.
Stability	Excluding the variations caused by the EUT MPPT, simulator output power should remain stable within 2 % of specified power level over the duration of the test: from the point where load balance is achieved until the island condition is cleared or the allowable run-on time is exceeded.
Fill factor [c]	0,25 to 0,8.

[a] For the purposes of this standard, it is assumed that there is no influence of cell technology on islanding detection.

[b] Response speed is indicated to avoid the influence caused by the MPPT control system, the ripple frequency on the DC side of a EUT, or the active methods of anti-islanding.

[c] Fill factor = $(V_{mp} \times I_{mp})/(V_{oc} \times I_{sc})$, where V_{mp} and I_{mp} are the maximum power point voltage and current, respectively, V_{oc} is the open circuit voltage, and I_{sc} is the short circuit current. It should be maintained at one value for all test conditions.

5.2.3 Current and voltage limited DC power supply with series resistance

A DC power source used as the EUT input source shall be capable of EUT maximum input power (so as to achieve EUT maximum output power) at minimum and maximum EUT input operating voltage.

The power source should provide adjustable current and voltage limit, set to provide the desired short circuit current and open circuit voltage when combined with the series and shunt resistance described below.

A series resistance (and, optionally, a shunt resistance) should be selected to provide a fill factor within the range shown in Table 2.

5.2.4 PV array

A PV array used as the EUT input source shall be capable of EUT maximum input power at minimum and maximum EUT input operating voltage (see Table 3). Testing is limited to times when the irradiance varies by no more than 2 % over the duration of the test as measured by a silicon-type pyranometer or reference device. It may be necessary to adjust the array configuration to achieve the input voltage and power levels prescribed in 6.1.

Table 3 – PV array test conditions

Items	Conditions
Output power	Sufficient to provide maximum EUT output power and other levels specified by test conditions of Table 5.
Climate condition	Irradiance, ambient temperature, etc.
To achieve a balanced load condition, the output of the PV array shall be stable. Thus, it is important to perform the test only during times of stable irradiance (e.g., clear sky, near solar noon).	

5.3 AC power source

The utility grid or other AC power source may be used as long as it meets the conditions specified in Table 4.

Table 4 – AC power source requirements

Items	Conditions
Voltage	Nominal ± 2,0 %
Voltage THD	< 2,5 %
Frequency	Nominal ± 0,1 Hz
Phase angle distance [a]	120° ± 1,5°
[a] Three-phase case only.	

5.4 AC loads

On the AC side of the EUT, variable resistance, capacitance, and inductance shall be connected in parallel as loads between the EUT and the AC power source. Other sources of load, such as electronic loads, may be used if it can be shown that the source does not cause results that are different than would be obtained with passive resistors, inductors, and capacitors.

All AC loads shall be rated for and adjustable to all test conditions. The equations for Q_f are based upon an ideal parallel RLC circuit. For this reason, non-inductive resistors, low loss (high Q_f) inductors, and capacitors with low effective series resistance and effective series inductance shall be utilized in the test circuit. Iron core inductors, if used, shall not exceed a current THD of 2 % when operated at nominal voltage. Load components should be conservatively rated for the voltage and power levels expected. Resistor power ratings should be chosen so as to minimize thermally-induced drift in resistance values during the course of the test.

Active and reactive power should be calculated (using the measurements provided in Table 1) in each of the R, L and C legs of the load so that these parasitic parameters (and parasitics introduced by variacs or autotransformers) are properly accounted for when calculating Q_f.

6 Test for single or multi-phase inverter

6.1 Test procedure

The following test is designed for an EUT consisting of a single or multi-phase inverter[1]. The test uses an RLC load, resonant at the EUT nominal frequency (50 Hz or 60 Hz) and matched to the EUT output power. For a multi-phase EUT, the load shall be balanced across all phases

1 Annex B describes the test for an independent islanding detection device (relay).