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Maximum power point tracking efficiency of grid connected photovoltaic inverters

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

MAXIMUM POWER POINT TRACKING EFFICIENCY OF GRID CONNECTED PHOTOVOLTAIC INVERTERS

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International Standard IEC 62891 has been prepared by IEC technical committee 82: Solar photovoltaic energy systems.

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

FDIS	Report on voting
82/1723/FDIS	82/1736/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 website under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
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MAXIMUM POWER POINT TRACKING EFFICIENCY OF GRID CONNECTED PHOTOVOLTAIC INVERTERS

1 Scope

This document provides a procedure for the measurement of the efficiency of the maximum power point tracking (MPPT) of inverters used in grid-connected photovoltaic (PV) systems. Both the static and dynamic MPPT efficiency are considered. Based on the static MPPT efficiency calculated in this document and steady state conversion efficiency determined in IEC 61683 the overall efficiency can be calculated.

The dynamic MPPT efficiency is indicated separately.

NOTE This document addresses PV inverters connected to an AC grid. However, this procedure may also be used for other power conversion devices with MPPT functionality used in PV systems, such as charge controllers or optimizers.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 61683, *Photovoltaic systems – Power conditioners – Procedure for measuring efficiency*

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

EN 50160, *Voltage characteristics of electricity supplied by public distribution networks*

3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1 Inverter input (PV generator)

3.1.1
maximum input voltage
V_{DCmax}
allowed maximum voltage at the inverter input

Note 1 to entry: Exceeding of V_{DCmax} may destroy the equipment under test.

3.1.2
minimum input voltage
$V_{\mathbf{DCmin}}$
minimum input voltage for the inverter to energize the utility grid, independent of mode of operation

3.1.3
rated input voltage
$V_{\mathbf{DC,r}}$
input voltage specified by the manufacturer, to which other data sheet information refers

3.1.4
maximum MPP voltage
$V_{\mathbf{MPPmax}}$
maximum voltage at which the inverter can convert its rated power under MPPT conditions

3.1.5
minimum MPP voltage
$V_{\mathbf{MPPmin}}$
minimum voltage at which the inverter can convert its rated power under MPPT conditions

Note 1 to entry: The actual minimum MPP voltage may depend on the grid voltage level.

3.1.6
rated input power
$P_{\mathbf{DC,r}}$
rated input power of the inverter, which can be converted under continuous operating conditions

3.1.7
maximum input current
$I_{\mathbf{DC,max}}$
maximum input current of the inverter under continuous operating conditions

Note 1 to entry: At inverters with several independent inputs, this value may depend on the chosen input configuration.

3.2 Inverter output (grid)

3.2.1
rated grid voltage
$V_{\mathbf{AC,r}}$
utility grid voltage to which other data sheet information refers

3.2.2
rated power
$P_{\mathbf{AC,r}}$
active power the inverter can deliver in continuous operation

3.3 Measured quantities

3.3.1
PV simulator MPP-Power
$P_{\mathbf{MPP,\ PVS}}$
MPP power provided by the PV simulator

3.3.2
input power
$P_{\mathbf{DC}}$
measured input power of the device under test

3.3.3
PV simulator MPP voltage
$V_{\mathrm{MPP,\,PVS}}$
MPP voltage provided by the PV simulator

3.3.4
input voltage
V_{DC}
measured input voltage of the device under test

3.3.5
PV simulator MPP current
$I_{\mathrm{MPP,\,PVS}}$
MPP current provided by the PV simulator

3.3.6
input current
I_{DC}
measured input current of the device under test

3.3.7
output power
P_{AC}
measured AC output power of the device under test

3.3.8
output voltage
V_{AC}
measured AC voltage

3.3.9
output current
I_{AC}
measured AC output current of the device under test

3.4 Calculated quantities

3.4.1
MPPT efficiency, energetic
η_{MPPT}
ratio of the energy drawn by the device under test within a defined measuring period T_{M} to the energy provided theoretically by the PV simulator at the maximum power point (MPP):

$$\eta_{\mathrm{MPPT}} = \frac{\int_0^{T_{\mathrm{M}}} p_{\mathrm{DC}}(t)\cdot dt}{\int_0^{T_{\mathrm{M}}} p_{\mathrm{MPP}}(t)\cdot dt} \qquad (1)$$

where

$P_{\mathrm{DC}}(t)$ is the instantaneous value of the power drawn by the device under test;

$P_{\mathrm{MPP}}(t)$ is the instantaneous value of the MPP power provided theoretically by the PV simulator.

3.4.2
conversion efficiency, energetic
η_{conv}
.ratio of the energy delivered by the device under test at the AC terminal within a defined measuring period T_M to the energy accepted by the device under test at the DC terminal:

$$\eta_{conv} = \frac{\int_0^{T_M} p_{AC}(t) \cdot dt}{\int_0^{T_M} p_{DC}(t) \cdot dt} \tag{2}$$

where

$P_{AC}(t)$ is the instantaneous value of the delivered power at the AC terminal of the device under test;

$P_{DC}(t)$ is the instantaneous value of the accepted power at the DC terminal of the device under test.

3.4.3
overall efficiency, energetic
η_t
ratio of the energy delivered by the device under test at the AC terminals within a defined measuring period T_M to the energy provided theoretically by the PV simulator:

$$\eta_t = \frac{\int_0^{T_M} p_{AC}(t) \cdot dt}{\int_0^{T_M} p_{MPP}(t) \cdot dt} \text{ respectively } \eta_t = \eta_{conv} \cdot \eta_{MPPT} \tag{3}$$

3.5
photovoltaic array simulator
current source emulating the static and dynamic behaviour of a PV array, in particular the current-voltage characteristic (see IEC TS 61836).

Note 1 to entry: The requirements are outlined in Clause A.1.

4 MPPT efficiencies

4.1 General description

The MPPT efficiency describes the accuracy of an inverter to set its operating conditions to match the maximum power point on the characteristic curve of a PV generator. The overall MPPT efficiency is divided into static and dynamic efficiency components.

Because inverters with poor MPPT performance operate at a DC input voltage that is different from MPP voltage, and static power conversion efficiency depends on DC input voltage, the measurements of static MPPT efficiency and static power conversion efficiency according to 4.3 shall be performed simultaneously.

a) Static MPPT efficiency

The static MPPT efficiency is determined by means of measurement as follows:

$$\eta_{\text{MPPTstat}} = \frac{1}{P_{\text{MPP,PVS}} \cdot T_{\text{M}}} \sum_{i} V_{\text{DC},i} \cdot I_{\text{DC},i} \cdot \Delta T \tag{4}$$

where

$V_{\text{DC},i}$ is the sampled value of the inverter's input voltage;

$I_{\text{DC},i}$ is the sampled value of the inverter's input current;

T_{M} is the overall measuring period;

ΔT is the period between two subsequent sample values.

The static MPPT efficiency describes the accuracy of an inverter to regulate on the maximum power point on a given static characteristic curve of a PV generator.

$V_{\text{DC},i}$ and $I_{\text{DC},i}$ shall be sampled at the same time.

b) Dynamic MPPT efficiency

Variations of the irradiation intensity and the resulting transition of the inverter to the new operation point are not considered with the static MPPT efficiency. For the evaluation of this transient characteristic the dynamic MPPT efficiency is specified. The dynamic MPPT efficiency is defined as:

$$\eta_{\text{MPPTdyn}} = \frac{1}{\sum_{j} P_{\text{MPP,PVS},j} \cdot \Delta T_j} \sum_{i} V_{\text{DC},i} \cdot I_{\text{DC},i} \cdot \Delta T_i \tag{5}$$

where

ΔT_j is the period in which the power $P_{\text{MPP,PVS},j}$ is provided;

ΔT_i is the period in which the power $V_{\text{DC},i}$ and $I_{\text{DC},i}$ are sampled.

4.2 Test set-up

The generic test set-up for single phase grid connected inverters is depicted in Figure 1. The diagram can also be considered as a single-phase representation of a test-circuit for multi phase inverters.