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Photovoltaic pumping systems – Design qualification and performance measurements

Systèmes de pompage photovoltaïques – Qualification de la conception et mesures de performance

IEC 62253:2011

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

PHOTOVOLTAIC PUMPING SYSTEMS – DESIGN QUALIFICATION AND PERFORMANCE MEASUREMENTS

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International Standard IEC 62253 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
82/647/FDIS	82/656/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- withdrawn,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
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PHOTOVOLTAIC PUMPING SYSTEMS – DESIGN QUALIFICATION AND PERFORMANCE MEASUREMENTS

1 Scope and object

This International Standard defines the requirements for design, qualification and performance measurements of photovoltaic pumping systems in stand-alone operation. The outlined measurements are applicable for either indoor tests with PV generator simulator or outdoor tests using a real PV generator. This standard applies to systems with motor pump sets connected to the PV generator directly or via a converter (DC to DC or DC to AC). It does not apply to systems with electrical storage unless this storage is only used for the pump start up (< 100 Wh).

The goal is to establish a PV pumping system design verification procedure according to the specific environmental conditions. This Standard addresses the following pumping system design features:

- Power vs. flow rate characteristics at constant pumping head
- Pumping head vs. flow rate characteristics at constant speed
- System design parameters and requirements
- System specification
- Documentation requirements
- System design verification procedure

The object of this standard is to establish requirements in order to be able to verify the system performance characteristics of the PV pumping system. For this purpose the test set-up is outlined, the measurements and deviations to be taken are defined and a checklist for the data mining is established.

2 Normative references

The following referenced documents are indispensable for the application 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 60068-2-6, *Environmental testing – Part 2-6: Tests – Test Fc: Vibration (sinusoidal)*

IEC 60068-2-30, *Environmental testing – Part 2:30: Tests – Test Db: Damp heat, cyclic (12 + 12 h cycle)*

IEC 60146 (all parts), *Semiconductor converters – General requirements and line commutated converters*

IEC 60364-4-41, *Low-voltage electrical installations – Part 4-41: Protection for safety – Protection against electric shock*

IEC 60364-7-712, *Electrical installations of buildings – Part 7-712: Requirements for special installations or locations – Solar photovoltaic (PV) power supply systems*

IEC 60529, *Degree of protection provided by enclosures (IP Code)*

IEC 60947-1, *Low voltage switchgear and controlgear – Part 1: General rules*

IEC 61000-6-2, *Electromagnetic compatibility (EMC) – Part 6-2: Generic standards – Immunity for industrial environments*

IEC 61000-6-3, *Electromagnetic compatibility (EMC) – Part 6-3: Generic standards – Emission standard for residential, commercial and light-industrial environments*

IEC 61215, *Crystalline silicon terrestrial photovoltaic (PV) modules – Design qualification and type approval*

IEC 61646, *Thin-film terrestrial photovoltaic (PV) modules – Design qualification and type approval*

IEC 61683:1999, *Photovoltaic systems – Power conditioners – Procedure for measuring efficiency*

IEC 61725, *Analytical expression for daily solar profiles*

IEC 61730-1, *Photovoltaic (PV) module safety qualification – Part 1: Requirements for construction*

IEC 61730-2, *Photovoltaic (PV) module safety qualification – Part 2: Requirements for testing*

IEC 61800-3, *Adjustable speed electrical power drive systems – Part 3: EMC requirements and specific test methods*

IEC 62103, *Electronic equipment for use in power installations*

IEC 62109-1, *Safety of power converters for use in photovoltaic power systems – Part 1: General requirements*

IEC 62124:2004, *Photovoltaic (PV) stand-alone systems design verification*

IEC 62305-3, *Protection against lightning – Part 3: Physical damage to structures and life hazard*

IEC 62458, *Sound system equipment – Electroacoustical transducers – Measurement of large signal parameters*

IEC 62548[1], *Design requirements for photovoltaic (PV) arrays*

ISO/DIS 9905, *Technical specifications for centrifugal pumps – Class I (ISO 9905:1994)*

3 Terms, definitions, system-types and -parameters

3.1 Terms and definitions

3.1.1 PV converter

The PV converter converts the DC voltage of the PV generator into a high or low DC voltage or converts this DC voltage and/or DC current into one-phase or multi-phase alternating-current voltage or alternating current

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[1] To be published.

NOTE the PV converter may also include equipment for MPPT, monitoring, metering and for protection purposes.

3.1.2 PV pump aggregate

The PV pump aggregate consists of the pump (centrifugal pump, displacement volume pump) the driving motor and control

3.1.3 PV pump terminal cable

A PV pump terminal cable connects the PV converter and the pump aggregate

3.1.4 PV pump systems

A PV installation is comprised mainly of the following components and equipment:

PV generator, cabling, control unit (e.g. inverter, DC/DC converter, etc.), motor, pump and hydraulic piping

3.1.5 Photovoltaic pumping systems in stand-alone operation

Photovoltaic pumping systems in stand-alone operation are photovoltaic pumping systems with no connection to the grid

3.1.6 Impedance matching

DC/DC Converter, which may include MPPT or V/I tracking maybe with temperature correction

3.2 System-types and -parameters

For the purposes of testing, PV pumping systems can be divided into four categories as shown in Table 1. The measurement access points within the system define these categories.

Figure 1 illustrates the four basic arrangements, and defines the parameters that can be measured at each accessible point in the system. The parameters are defined in Table 2.

Table 1 – Categories of PV pumping systems for the purposes of testing

Pumping system types
A. DC systems either directly connected or with a control (impedance matching) electronics integral with motor-pump
B. DC system with separate impedance matching unit, connected to either brushed or electronics commutated motor-pump unit where the corresponding controls are integral with motor-pump
C. DC system (brushless) with separate commutation control (and impedance matching)
D. System with DC/AC inverter for operation of a standard AC pump-motor

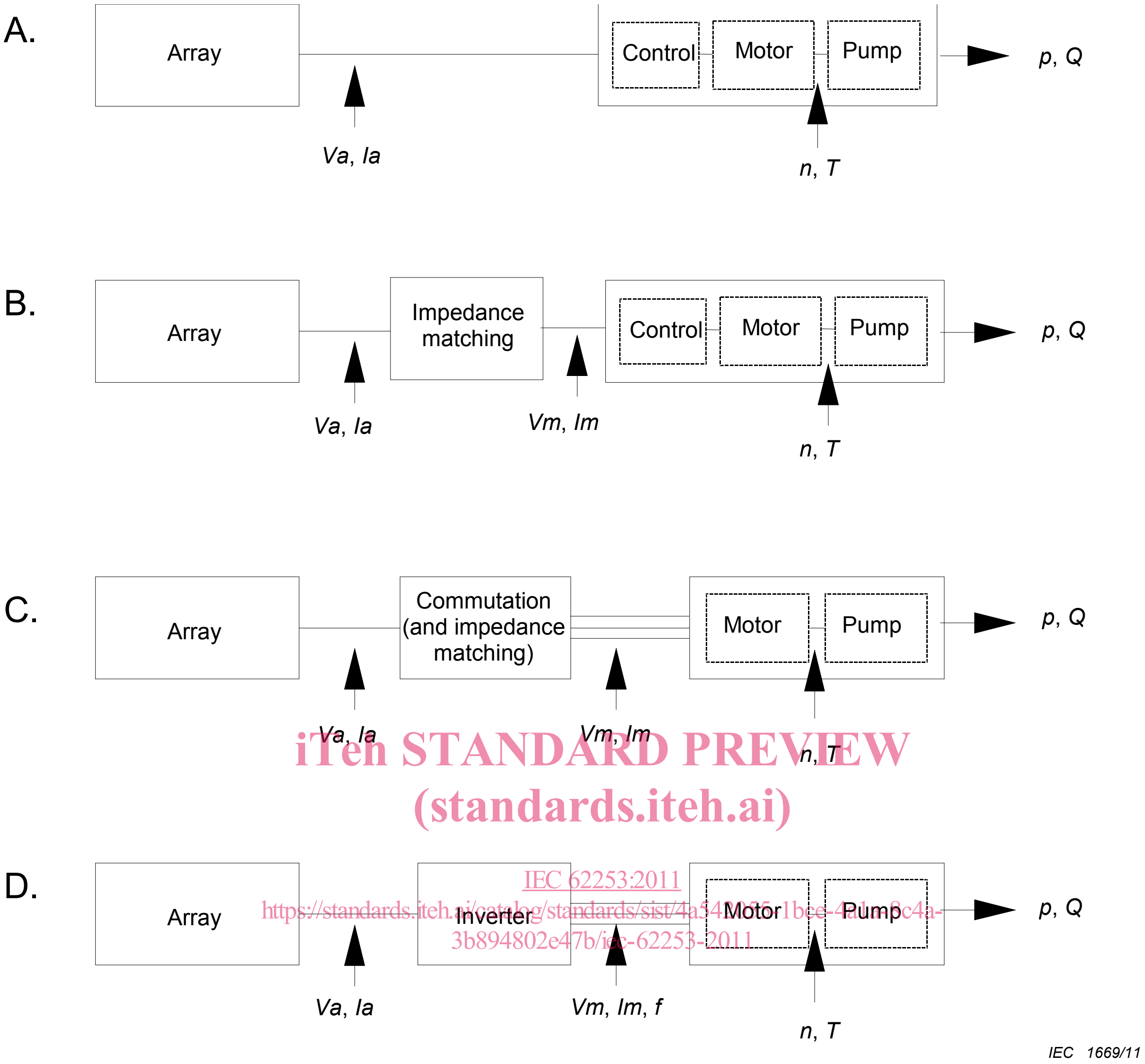

Figure 1 – Schematic of system types for the purposes of testing
(In case C, Vm and Im may be electronically commutated voltage and current)

Table 2 – Definition of the parameters

No.	Parameter	Sym	Unit
1	Generator voltage DC	*Va*	V
2	Generator current DC	*Ia*	A
3	Generator open circuit voltage DC	*Voc*	V
4	Generator short cut current DC	*Isc*	A
5	Generator maximum power point voltage DC	*Vmpp*	V
6	Generator maximum power point current DC	*Impp*	A
7	Pressure as measured	*p*	Pa
8	Flow rate	*Q*	m^3/h
9	Motor voltage DC or AC	*Vm*	V
10	Motor current DC or AC	*Im*	A
11	Motor voltage (multi-phase AC)	V_{rms}	V
12	Motor current (multi-phase AC)	I_{rms}	A
13	Power factor	λ	-
14	AC frequency (or DC switching frequency)	*f*	Hz
15	Motor speed	*n*	min^{-1}
16	Torque at motor-pump coupling	*T*	Nm
17	Water temperature (at inlet)	*t*	°C

4 Requirements for system components

4.1 General

Typically a PV pumping system consists of the following main components:

- PV generator
- Electronic converters which are separate (impedance matching device or inverter)
- Combined motor pump unit

4.2 Relations to other standards

PV pumping systems are one of the applications for photovoltaics. Therefore existing standards for the components shall be applied.

PV modules should comply with the requirements of relevant standards. For crystalline PV modules IEC 61215, for thin-film PV modules IEC 61646 and for safety requirements for PV modules IEC 61730-1 and IEC 61730-2 are applicable. PV generators should be installed according to IEC 62548. The PV generator combiner box should bear a warning label indicating that active parts of the PV generator combiner box may still be live even after disconnection from the converter.

As PV pumping systems are stand-alone systems IEC 60364-7-712 applies as well.

The PV generator combiner boxes and the switchgear assembly for the installation of the PV converter should be in compliance with the requirements of IEC 60947-1. A warning label is required to the extent that fuses or disconnect devices should not be withdrawn or switched under load if such devices are installed on the DC side.

Power Conditioning Units (DC-DC converter, DC-AC converter) have to fulfil the requirements given in IEC 62109-1.

Upon selection of the electrical equipment of the DC side one should ensure that the equipment is suited for direct voltage and direct current. PV generators are to be connected in series up to the maximum open-circuit voltage of the PV generator. The respective specifications are to be given by the module manufacturer. If blocking diodes are necessary, their reverse voltage is to be rated at twice the value of the open-circuit voltage of the PV generator under STC. IEC 62458 for PV installation shall be referred.

The protection concept should meet the requirements against electric shocks (IEC 60364-4-41) and the operation safety of the system. Testing of electrical components and electronic apparatus shall comply with IEC 60146, IEC 62103 and all relevant standards.

Lightning protection shall be compliant to the relevant standards and the requirements of IEC 62305-3.

The damp-heat suitability of electronic apparatus shall be compliant at local ambient conditions to IEC 60068-2-30 (ref. to damp-heat cyclic). 5 cycles shall be made for the electronic apparatus.

Severity: With plants for tropical application the temperature amounts to 55 °C max.
With plants in temperate climates the temperature amounts to 45 °C max.

Protection against contact, foreign bodies and water shall be compliant to IEC 60529.

Type testing of the transportability of electronic apparatus with packaging shall be compliant to IEC 60068-2-6.

Assessment of immunity against conducted and radiated disturbing quantities shall be compliant to IEC 61000-6-2, IEC 61000-6-3 and IEC 61800-3.

Pumps can be classified into 4 main categories, although supplementary types might exist.

Centrifugal pumps shall fulfil the requirements given in ISO/DIS 9905 Class I.

5 Performance measurement

5.1 General

The performance of the system can be determined by evaluation the complete system under varying conditions. The performance shall be evaluated either under laboratory (replicable and reproducible) conditions or under field conditions for acceptance test. One of them is enough.

5.2 Test set-up

The minimum requirement for a test set-up for performance measurement is defined as follows (Maximum measurement uncertainties are given in Table 4):

Electric:

- Real PV generator with irradiance and wind measurement (for field acceptance) or
  Programmable PV solar generator simulator capable to simulate a given PV solar generator configuration (i.e. the number of modules, the type and the series/parallel combination) for laboratory test.
- Real cable type, length and diameter (for field acceptance or laboratory test) or
  Cable impedance simulator (for laboratory test).

- Measurement equipment with acceptable accuracy and precision for detection and registration of the parameters listed in Table 2.

Hydraulic:

- Water tank
- Motor-pump set
- Pressure transducer
- Pre-pressurised air chamber (where the pressure level can be adjusted)
- Flow transducer
- Pressure sustaining device
- Discharge pipe

An example test circuit schematic is shown in Figure 2.

NOTE Any equivalent test circuit (e.g. for different pumping types) verifying correct hydraulic characteristics and system performance can be used, provided that it ensures the required initial counter pressure.

The pipe set up between the pump outlet and the pressure sensor should be the same diameter as the manufacturer's outlet fitting. It is assumed that over the normal operating range of the pump the pressure drop due to frictional losses between the pump outlet and the pressure sensor will be negligible and the kinetic energy component of the water at the pump outlet will be small compared to the increase in potential energy due to the increased pressure across the pump. These assumptions should be verified and if necessary the effect on the calculation of hydraulic power should be corrected. This should be noted in the test report.

The general layout of the system pipe work should be designed to avoid airlocks.

For instantaneous performance testing, pressure can be sustained by means of a simple gate valve in which a backpressure is sustained by restricting the flow. There are also special valves available which sustain a constant upstream pressure (pressure sustaining valves) although care should be taken, as their performance can be unpredictable. Some better equipped test laboratories may sustain pressure by means of a pre-pressurised air chamber operating with a pressure maintaining valve at the outlet or a real water column (see Table 3).

If a flow meter is used for laboratory measurements, then the end of the discharge pipe should be beneath the water surface to prevent splashing. This could cause a mixed water / air bubbles fluid entering the pump inlet and affecting its proper operation. If the bucket and stop-watch method (field method) is used, it is not possible to discharge the water beneath the surface, and so a vertical baffle shall be inserted in the tank between the pump intake and the return pipe such that water has to pass under the baffle near the bottom of the tank to reach the pump. In this way any small bubbles will be excluded, as they will remain near the surface. Alternatively a large pipe can be placed around the pump with its top breaking the surface and an arch cut in its base to allow water entry.

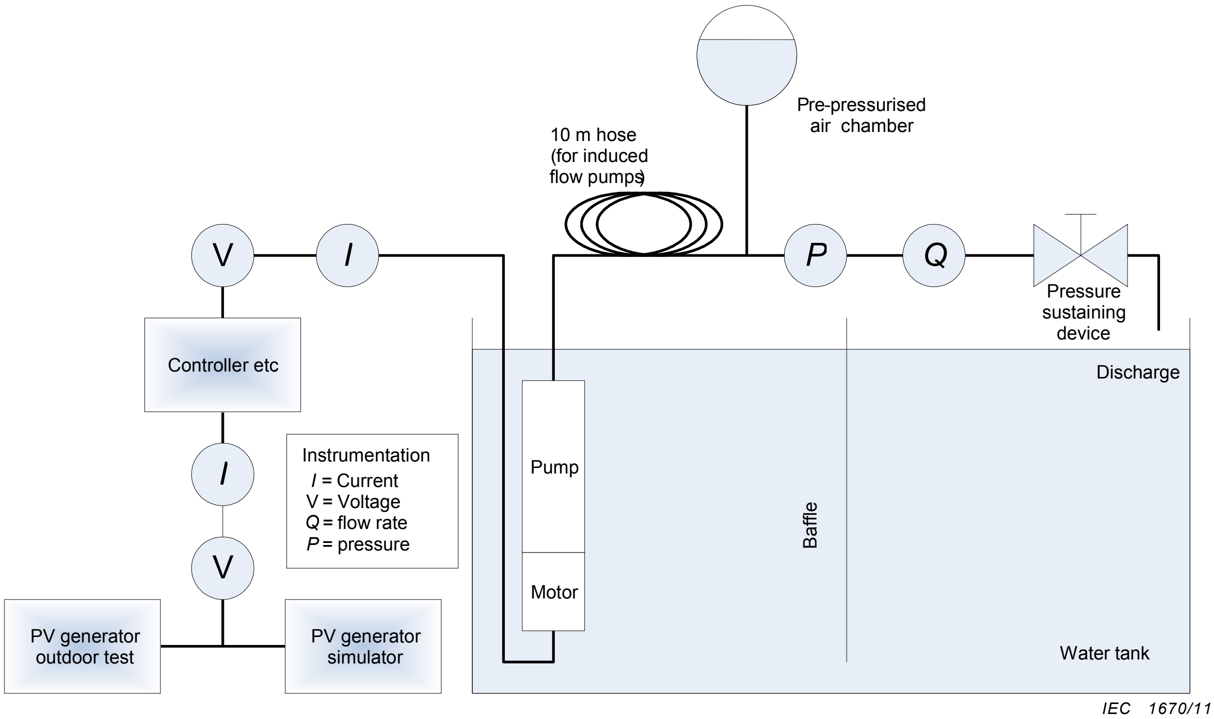

Figure 2 – Example of PV pump test circuit in the lab

5.3 Pumping system performance tests

5.3.1 General

The characteristics agreed to in the component and implementation specification shall be verified in the performance tests. During the performance test, components or subsystems are submitted to various test procedures and are tested for adherence to the stipulated characteristics. A first design check will be carried out after the performance curves have been determined to compare them with the required design data of the plant. Data for the system as a whole is verified on site by performing the field performance test. The test provides all necessary information and performance curves to be taken as a basic for the field performance test.

Laboratory performance test: A schematic of the required laboratory system test circuit is shown in Figure 2.

The converter efficiency test is performed according to IEC 61683:1999 and therefore not detailed in this standard.

5.3.2 P-Q characterisation

It is important to test the performance of the pumping systems at constant head (H) and varying input power (P) to determine the resultant flow rate (Q). In the laboratory these characteristic constant head (H) curves for P over Q shall be determined.

The following constant head (H) curves should be determined (unless the manufacturer defines the lowest allowed head different. Then H_1 should be taken as H_{min}):

$H_1 =$ 0,3 H_{max}

$H_2 =$ 0,4 H_{max}