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Edition 1.0 2024-04

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Solar thermal electric plants –
Part 1-5: Performance test code for solar thermal electric plants

Centrales électriques solaires thermodynamiques –
Partie 1-5: Code d'essai de performance pour centrales électriques solaires thermodynamiques

IEC 62862-1-5:2024-04(en-fr)

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FOREWORD

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The text of this International Standard is based on the following documents:

Draft	Report on voting
117/177/CDV	117/191/RVC

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

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

A list of all parts in the IEC 62862 series, published under the general title *Solar thermal electric plants*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn, or
- revised.

INTRODUCTION

Solar thermal power plants are electricity generation plants that use solar radiation to heat a fluid to a high temperature. This fluid usually transfers its heat to water to produce superheated steam, which is expanded in a turbine-generator machine to transform thermal energy first into mechanical energy and finally into electricity. These plants use solar collectors to concentrate the solar radiation, and they are classified depending on the concentration technology, including but not limited to parabolic-trough collector (PTC), central receiver collector (CRC) also called solar tower, and linear Fresnel collector (LFC).

Solar thermal power plants are composed of a solar field interconnected to a power block, but sometimes they also include a non-solar energy source and a thermal storage system which enable electricity generation under conditions of reduced or no solar radiation (see Figure 1). Depending on the concentration technology, the solar field can consist of a set of parabolic-trough collector rows, linear Fresnel collector rows, or a set of heliostats with a central receiver located in a tower. All these systems track the sun and collect the energy that it projects in the form of direct radiation.

The plant performance should be demonstrated, or verified, as part of the commissioning and acceptance process, for all the configurations agreed by the parties involved.

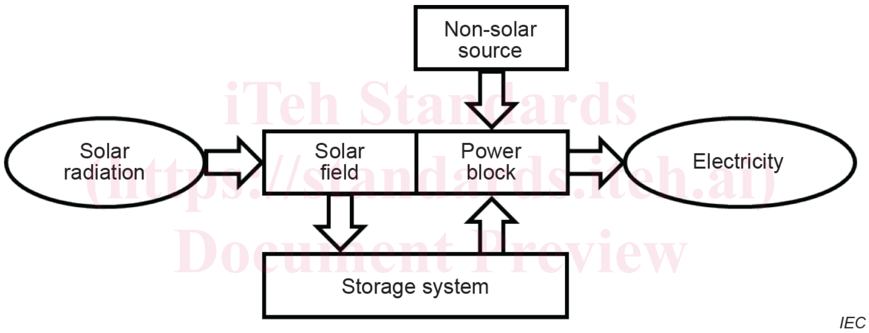

Figure 1 – Energy flows in a solar thermal power plant

The complexity and duration of performance acceptance tests depend on what these tests are for. There are several different types of tests:

- Short quasi-stationary tests: Their purpose is to verify the characteristics and features of the power plant systems (solar field, thermal storage system, power block, and auxiliary non-solar energy systems).
- Short-duration testing (at least 24 h): The purpose is to verify the performance of the power plant over a short period of time (usually associated with provisional plant acceptance testing).
- Long-duration tests (at least 365 days): The purpose is to verify or validate annual plant production and auxiliary consumptions (electricity and non-solar energy source). (These tests are usually associated with final plant acceptance.)
- Dispatchability tests: The purpose is to verify the ability of the solar thermal power plant to respond to grid operator signals regardless of meteorological conditions.
- Durability and integrity testing: The purpose is to verify integrity and validate equipment durability.

This document focuses on acceptance testing of the complete power plant and defines the measurement procedures for short-duration and long-duration efficiency testing.

SOLAR THERMAL ELECTRIC PLANTS –

Part 1-5: Performance test code for solar thermal electric plants

1 Scope

The purpose of this document is to provide procedures and guidelines to carry out acceptance tests for solar thermal power plants, of any concentration technology, with the uncertainty level given in ISO/IEC Guide 98-3.

This document establishes the measurements, instrumentation and techniques required for determining the following performance parameters for a given period:

- available solar radiation energy,
- plant electricity consumptions,
- net electricity generation,
- non-solar energy,
- net plant efficiency.

Other parameters that characterize the solar thermal power plant system features are not dealt with in this document but are the subject of other complementary standards.

This document specifies the characteristics of a calculation tool that serves as a reference for expected electricity production during the test period and under the real-time solar irradiance and other meteorological data.

This document is applicable to solar thermal power plants of any size using any concentration technology, where the sun is the main source of energy, and all elements and systems are operative. Such power plants can optionally have non-solar energy sources, such as natural gas or other renewable energies, and a thermal storage system.

This document is applicable to acceptance testing in such power plants, as well as in any other scenario in which their performance must be known. Acceptance tests serve for the purpose of verification of a contractual performance measure, and for establishing claims in case of non-fulfillment of performance. In this document the owner, builder, financier, and any other entity interested in knowing these features are called "parties involved".

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 60044-7, *Instrument transformers – Part 7: Electronic voltage transformers*

IEC 60044-8, *Instrument transformers – Part 8: Electronic current transformers*

IEC TS 62862-1-1, *Solar thermal electric plants – Part 1-1: Terminology*

ISO/IEC Guide 98-3, *Uncertainty of measurement – Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC TS 62862-1-1 apply.

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

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

4 Symbols

The symbols and units used in this document are displayed in Table 1.

Table 1 – Symbols and units

Symbol	Description	Units
A_{net}	Net collection area	m^2
C_p	Specific heat capacity	J/(kg·K)
E_b	Direct normal solar irradiance	W/m^2
$E_{el,net}$	Net electricity generated and delivered to the grid	kWh
E_{ns}	Thermal energy supplied by fossil fuels and/or other non-solar energies	kWh
h	Specific enthalpy	J/kg
$\dot{m}$	Mass flow rate	kg/s
N_{col}	Number of single elements in operation in the solar field: parabolic-trough collectors, Fresnel reflectors or heliostats	-
P	Power	kW
p_{atm}	Atmospheric pressure	Pa
RH	Relative humidity	%
t	Time	h
T	Temperature	°C
U_B	Type B uncertainty	
v	Wind speed	m/s
$\dot{V}$	Volumetric flow	m^3/s
Greek symbols		
Δ	Difference or variation	-
$\eta_{plant,net}$	Net plant efficiency	%
ρ	Density	kg/m^3
τ	Test time	s
Subscripts		
accum	cumulative value	
atm	atmospheric	
aux	at auxiliary transformer high voltage side	

Symbol	Description	Units
avail	available in the aperture area of the plant solar field	
con	consumption	
el	electricity	
gross	at generator terminals	
HTF	heat transfer fluid	
i, j	time interval, index	
in, out	inlet, outlet	
net	net value	
ns	non solar	
plant	related to the power plant	
solar	solar radiation	
startup	at startup transformer high voltage side	
tr	transformer	
trloss	transformer losses	
util	useful	
0, end	initial and final time	

5 Performance reference

5.1 Requirements

According to this document, the verification of performance for a solar thermal power plant requires:

a) The use of a power plant simulation model, hereinafter "simulation model", to generate reference values from the input and boundary conditions existing during a test.
b) To define the verification procedure, that is, the way measurements are to be compared with the reference considering uncertainties.

Subclause 5.2 defines the simulation model, while the verification procedure is defined in 8.8.

5.2 Simulation model

This document establishes that the simulation model of the tested solar power plant and its systems is an essential element in the acceptance process. The simulation model to be used shall be agreed by the parties involved, and its validation shall be documented. It is recommended that the simulation model meet at least the requirements listed in Clause 5.

Owing to the importance of inertial and transient phenomena during performance tests, the simulation model shall be dynamic, or at least consider solar field inertia phenomena, to be able to calculate the reference performance indicators, like electrical power or plant efficiency, for the test boundary conditions.

For short-duration and long-duration efficiency tests, the simulation model will commonly include the following inputs and outputs (see Figure 2):

- Input specifications:
  - power plant location (geographic latitude and longitude);
  - test start and end dates and times;

  - date and time, direct solar irradiance, and other meteorological conditions during testing (temperature, wind speed, atmospheric pressure, relative humidity, and, if needed by the simulation model, wind direction), recorded in time intervals no longer than 10 min and averaged as specified in 8.6;
  - plant operating modes during testing;
  - solar field and power plant availability during testing;
  - reflectance of mirrors in the solar field over time;
  - starting conditions of the thermal storage system;
  - starting conditions of the power plant when testing begins (type of startup);
  - non-solar energy consumption during testing.
- Output specifications:
  - available solar radiation energy;
  - net electricity production (at test boundaries);
  - auxiliary electricity consumption;
  - consumption of electricity imported from the grid.

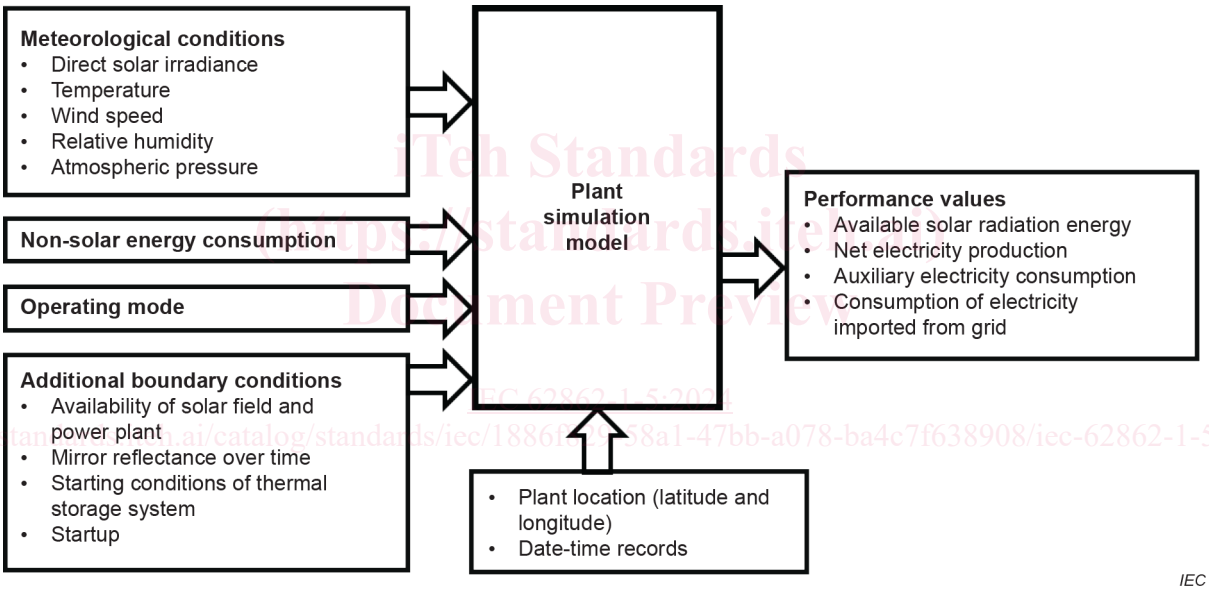

Figure 2 – Required simulation model inputs and outputs

The simulation model used in the acceptance process shall be previously validated and agreed upon by the parties involved. It is recommended that the simulation model validation include the following:

- Verification that the simulation model reproduces nominal performance values at reference conditions (i.e., design point conditions).
- Consistency in predicting performance values at conditions other than those of reference, showing that when input parameters are varied, output trends are congruent with these variations.

6 General test guidelines

6.1 General

Clause 6 provides the general instructions to carry out performance tests for solar thermal power plants, with the steps required to plan, prepare, and perform them.

6.2 Test procedure

The test procedure is a detailed document on the test plan, which shall be prepared and approved beforehand by the parties involved. This basic document shall include all the details for preparing and conducting a test, as well as how to make calculations and report the results.

It is recommended that it includes at least the following:

1) Purpose of the test, indicating foreseen duration.
2) Features to be verified, along with their guaranteed values and uncertainty margins, if applicable.
3) Test boundaries, identifying the input and output flows and measurement points.
4) Basic test plan.
5) Description of the activities to be performed during test preparation, such as calibration and verification of measurement equipment, training of personnel who take part in the test, inspection and cleaning of equipment, and carrying out a pretest if so agreed. The instrumentation that is to be used during the tests shall meet the specifications defined in Clause 7. All measuring equipment, both permanent and temporary instruments, necessary for the test, shall be checked, inspected, and tuned before starting the test.
6) Description of activities to be carried out during the test, such as checking the conditions necessary to start, interrupt, suspend or end the test, operating conditions, adjustments permitted before and during the test, and details about data recording. The test conditions shall not at any time surpass the maximum limits of the equipment involved, as set by their suppliers, nor those of the normal plant operating procedures.
7) Description of plant operating conditions, including both major and auxiliary equipment that affect test results.
8) Procedure for determining the solar field cleanliness factor.
9) List of plant instruments and measuring equipment, including tag, description, calibration, location, number, type, uncertainty (accuracy) and main technical data.
10) Calibration certificates of listed instruments.
11) Prior uncertainty analysis, establishing the uncertainties estimated by non-statistical procedures.
12) Methodology for determining the meteorological variables, such as direct normal radiation, wind speed, atmospheric pressure, ambient temperature and relative humidity.
13) Sampling methods for the heat transfer fluid, the storage medium or the non-solar energy sources, if any. Indication of preparation, sampling frequency, parameters to be determined, and analysis methods.
14) Identification of the laboratory that will analyze the heat transfer fluid and storage medium or non-solar energy source, if any.
15) Thermo-physical property tables for heat transfer fluid and storage medium or non-solar energy source, if any.
16) Format in which data and results will be recorded and supplied.
17) Data averaging and validation procedures for redundant measurements.
18) Data verification and rejection criteria. Procedure to solve data acquisition system (DAS) failures, generating gaps in the records, with criteria to complete or discard such periods.
19) Data distribution procedure. The measured data shall be stored in electronic data files that shall be available to the parties involved. Processed values and calculations derived from these data shall be done in different files from the original files. Final reports on results shall include the original data files.
20) Specific reference and description of the simulation model used to obtain acceptance criteria. It shall include acceptable deviation limits between measured and calculated values using the simulation model, considering uncertainties.
21) Procedure for determining the effect of degradation of plant components, if applicable.

22) Procedure for verifying plant performance.

If the parties involved consider it advisable, any of the above can be excluded.

6.3 Guidelines for each type of test

6.3.1 General

Within the scope of this document, guidelines for two types of performance tests are given: short-duration (at least 24 h), and long-duration (at least 365 days). The specific duration, agreed by the parties, shall be indicated in the test procedure.

For short-duration tests, it is recommended to keep the thermal storage inactive. But in cases where the use of the thermal storage system, if any, was necessary, a procedure shall be considered to check the complete charge/discharge of the system during the test period; for example, recording initial and final temperatures and levels.

For long-duration tests, the influence on the calculated efficiency of the difference between initial and final thermal storage conditions is negligible.

6.3.2 Short-duration tests

The purpose of short-duration tests is to verify plant performance for at least 24 h. The operating parameters required for acceptance of the complete solar thermal power plant during these tests are available solar radiation energy, net electricity generation, electricity consumption, non-solar energy consumption and net efficiency.

It is recommended that a short pretest be done, for example during a couple of hours before beginning the short-duration test, to check that the plant meets the conditions to start the test and that the measurement equipment and DAS are working properly. The pretest is also used to analyze whether system adjustments are necessary before starting the plant performance acceptance test. Specifications for the pretest shall be stipulated in the test procedure.

Short-duration tests shall last at least 24 h to enable evaluation of the plant, taking into account all subsystems and operating modes in which plant performance is to be verified. If the solar thermal power plant has a thermal storage system, the test to verify overall plant efficiency shall be long enough to include the complete charge/discharge process from beginning to end of testing.

For short-duration performance tests, the parties involved shall agree on the conditions under which the tests are to be performed and define them in the test procedure. It is suggested that the test be repeated at least three times to reduce uncertainties.

All instruments used shall be checked before the test. After the test, instruments suspected of abnormalities should be rechecked. The result of these checks shall be collected in a report that also includes the calibration certificates. These reports shall be distributed among the parties.

It is recommended that the heat transfer fluid temperature be homogenized in the solar thermal power plant before beginning the test.

The short-duration tests shall be done on clear days and with a maximum direct solar irradiance of no less than 700 W/m^2 for at least 4 h. A clear day is understood to be one on which possible solar radiation transients do not surpass 5 % of sunlight hours. A solar radiation transient means a time interval of no longer than 30 min, in which the solar radiation is significantly lowered due to clouds, recording a clarity index below 0,5 for the period in consideration. The clarity index is defined as the quotient of global horizontal irradiance and the product of extraterrestrial solar irradiance by the cosine of the solar zenith angle (according to ISO 9488). In those cases, in