IEC 62862-1-5

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)



THIS PUBLICATION IS COPYRIGHT PROTECTED

Copyright © 2024 IEC, Geneva, Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either IEC or IEC's member National Committee in the country of the requester. If you have any questions about IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

Droits de reproduction réservés. Sauf indication contraire, aucune partie de cette publication ne peut être reproduite ni utilisée sous quelque forme que ce soit et par aucun procédé, électronique ou mécanique, y compris la photocopie et les microfilms, sans l'accord écrit de l'IEC ou du Comité national de l'IEC du pays du demandeur. Si vous avez des questions sur le copyright de l'IEC ou si vous désirez obtenir des droits supplémentaires sur cette publication, utilisez les coordonnées ci-après ou contactez le Comité national de l'IEC de votre pays de résidence.

IEC Secretariat
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

About the IEC
The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications
The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigendum or an amendment might have been published.

IEC publications search - webstore.iec.ch/advsearchform
The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee, …). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished
Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and once a month by email.

IEC Customer Service Centre - webstore.iec.ch/csc
If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: sales@iec.ch.

IEC Products & Services Portal - products.iec.ch
Discover our powerful search engine and read freely all the publications previews, graphical symbols and the glossary. With a subscription you will always have access to up to date content tailored to your needs.

Electropedia - www.electropedia.org
The world's leading online dictionary on electrotechnology, containing more than 22 500 terminological entries in English and French, with equivalent terms in 25 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

A propos de l'IEC
La Commission Electrotechnique Internationale (IEC) est la première organisation mondiale qui élabore et publie des Normes internationales pour tout ce qui a trait à l'électricité, à l'électronique et aux technologies apparentées.

A propos des publications IEC
Le contenu technique des publications IEC est constamment revu. Veuillez vous assurer que vous possédez l'édition la plus récente, un corrigendum ou amendement peut avoir été publié.

Recherche de publications IEC - webstore.iec.ch/advsearchform
La recherche avancée permet de trouver des publications IEC en utilisant différents critères (numéro de référence, texte, comité d'études, …). Elle donne aussi des informations sur les projets et les publications remplacées ou retirées.

IEC Just Published - webstore.iec.ch/justpublished
Restez informé sur les nouvelles publications IEC. Just Published détaille les nouvelles publications parues. Disponible en ligne et une fois par mois par email.

Service Clients - webstore.iec.ch/csc
Si vous désirez nous donner des commentaires sur cette publication ou si vous avez des questions contactez-nous: sales@iec.ch.

IEC Products & Services Portal - products.iec.ch
Découvrez notre puissant moteur de recherche et consultez gratuitement tous les aperçus des publications, symboles graphiques et le glossaire. Avec un abonnement, vous aurez toujours accès à un contenu à jour adapté à vos besoins.

Electropedia - www.electropedia.org
Le premier dictionnaire d'électrotechnologie en ligne au monde, avec plus de 22 500 articles terminologiques en anglais et en français, ainsi que les termes équivalents dans 25 langues additionnelles. Egalement appelé Vocabulaire Electrotechnique International (IEV) en ligne.

IEC 62862-1-5

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

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

ICS 27.160

ISBN 978-2-8322-8292-2

Warning! Make sure that you obtained this publication from an authorized distributor.
Attention! Veuillez vous assurer que vous avez obtenu cette publication via un distributeur agréé.

® Registered trademark of the International Electrotechnical Commission
Marque déposée de la Commission Electrotechnique Internationale

CONTENTS

FOREWORD 4
INTRODUCTION 6
1 Scope 7
2 Normative references 7
3 Terms and definitions 8
4 Symbols 8
5 Performance reference 9
5.1 Requirements 9
5.2 Simulation model 9
6 General test guidelines 10
6.1 General 10
6.2 Test procedure 11
6.3 Guidelines for each type of test 12
6.3.1 General 12
6.3.2 Short-duration tests 12
6.3.3 Long-duration tests 13
6.4 Test boundary 13
7 Instruments and methods of measurement 14
7.1 General 14
7.2 General requirements 14
7.3 Required measurements 14
7.3.1 Direct solar irradiance 14
7.3.2 Heat transfer fluid flow rate 16
7.3.3 Temperatures 16
7.3.4 Wind speed 17
7.3.5 Relative humidity 17
7.3.6 Atmospheric pressure 17
7.3.7 Net plant electricity generation: delivered electricity to the grid minus received electricity from the grid 17
7.3.8 Electricity consumption at auxiliary transformer 18
8 Performance calculations 18
8.1 Available solar radiation energy 18
8.2 Plant electricity consumption 19
8.3 Net electricity 19
8.4 Non-solar energy 20
8.5 Net plant efficiency 20
8.6 Recording and processing data 21
8.7 Results presentation 21
8.8 Acceptance test procedure 22
9 Performance test report 23
9.1 General 23
9.2 Executive summary 23
9.3 Introduction 23
9.4 Instrumentation 24
9.5 Calculations and results 24
9.6 Conclusions 24

9.7 Annexes 24
Annex A (normative) Uncertainty calculation 25
A.1 Purpose and assumptions 25
A.2 Equations for calculating net plant efficiency 25
A.3 Considerations for calculating uncertainties 26
A.4 Basic equations for calculating uncertainties 27
A.5 Calculating uncertainties 27
A.5.1 General 27
A.5.2 Type B uncertainty of the direct solar irradiance 29
A.5.3 Type B uncertainty of the electrical power 29
A.5.4 Type B uncertainty of the mass flow rate of heat transfer fluid in the auxiliary heater 29
A.5.5 Type B uncertainty of the enthalpy difference of heat transfer fluid in the auxiliary heater 31
A.6 Alternative method for calculating the uncertainty of net plant efficiency 31
A.7 Calculation of Type B standard uncertainty when redundant instruments are used 32
A.7.1 General 32
A.7.2 Type B standard uncertainty of temperatures measured with two redundant sensors 32
A.7.3 Type B standard uncertainty of direct solar irradiance 32
Annex B (informative) Example of uncertainty of net efficiency calculated following the procedure in Clause A.5 34
B.1 General 34
B.2 Technical data of instruments and DAS 35
B.2.1 Measured electrical power 35
B.2.2 Temperature 35
B.2.3 Flow rate 35
B.2.4 Direct solar irradiance 35
Annex C (informative) Example of uncertainty of net efficiency calculated following the alternative procedure described in Clause A.6 40
C.1 General 40
C.2 Step 1: 40
C.3 Step 2: 41
C.4 Step 3: 41
Bibliography 42

Figure 1 – Energy flows in a solar thermal power plant 6
Figure 2 – Required simulation model inputs and outputs 10
Figure 3 – Generic test boundary and energy flows 14
Figure 4 – Typical electrical connections in a power plant 18
Figure 5 – Examples of acceptance criteria – Comparison of the measured value (M) against the reference value (RV) with uncertainty bands 23

Table 1 – Symbols and units 8
Table 2 – Example of a test main results table 21
Table 3 – Levels of confidence and associated coverage factors (Normal distribution) 22
Table B.1 – Test values 34
Table C.1 – Test values 40

INTERNATIONAL ELECTROTECHNICAL COMMISSION

_____

SOLAR THERMAL ELECTRIC PLANTS –

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

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as “IEC Publication(s)”). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
6) All users should ensure that they have the latest edition of this publication.
7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
9) IEC draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). IEC takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, IEC had not received notice of (a) patent(s), which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at https://patents.iec.ch. IEC shall not be held responsible for identifying any or all such patent rights.

IEC 62862-1-5 has been prepared by IEC technical committee TC 117: Solar thermal electric plants. It is an International Standard.

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.

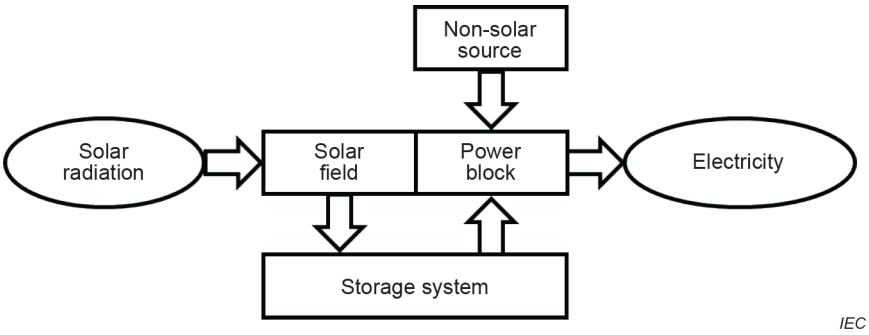


Figure 1 – Energy flows in a solar thermal power plant

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	ºC
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	