

1526™

IEEE Recommended Practice for Testing the Performance of Stand-Alone Photovoltaic Systems

IEEE Standards Coordinating Committee 21

Sponsored by the
IEEE Standards Coordinating Committee 21 on
Fuel Cells, Photovoltaics, Dispersed Generation,
and Energy Storage (SCC21)



Published by
The Institute of Electrical and Electronics Engineers, Inc.
3 Park Avenue, New York, NY 10016-5997, USA

29 January 2004

Print: SH95177
PDF: SS95177

IEEE Recommended Practice for Testing the Performance of Stand-Alone Photovoltaic Systems

Sponsor

IEEE Standards Coordinating Committee 21 on Fuel Cells, Photovoltaics, Dispersed Generation, and Energy Storage (SCC21)

Approved 11 September 2003

Reaffirmed 9 December 2009

IEEE-SA Standards Board

Approved 29 December 2003

American National Standards Institute

Abstract: Tests to determine the performance of stand-alone photovoltaic (PV) systems and for verifying PV system design are presented in this recommended practice. These tests apply only to complete systems with a defined load. Performance testing is conducted outdoors under prevailing conditions over a period of about one month. The tests are intended to assist designers, manufacturers, system integrators, system users, and laboratories that will conduct the tests. System safety and component reliability issues are not addressed in this recommended practice.

Keywords: design verification, performance testing, stand-alone photovoltaic (PV) system

The Institute of Electrical and Electronics Engineers, Inc.
3 Park Avenue, New York, NY 10016-5997, USA

Copyright © 2004 by the Institute of Electrical and Electronics Engineers, Inc.
All rights reserved. Published 29 January 2004. Printed in the United States of America.

IEEE is a registered trademark in the U.S. Patent & Trademark Office, owned by the Institute of Electrical and Electronics Engineers, Incorporated.

National Electrical Code and NEC are both registered trademarks in the U.S. Patent & Trademark Office, owned by the National Fire Protection Association, Incorporated.

Print: ISBN 0-7381-3828-2 SH95177
PDF: ISBN 0-7381-3829-0 SS95177

No part of this publication may be reproduced in any form, in an electronic retrieval system or otherwise, without the prior written permission of the publisher.

IEEE Standards documents are developed within the IEEE Societies and the Standards Coordinating Committees of the IEEE Standards Association (IEEE-SA) Standards Board. The IEEE develops its standards through a consensus development process, approved by the American National Standards Institute, which brings together volunteers representing varied viewpoints and interests to achieve the final product. Volunteers are not necessarily members of the Institute and serve without compensation. While the IEEE administers the process and establishes rules to promote fairness in the consensus development process, the IEEE does not independently evaluate, test, or verify the accuracy of any of the information contained in its standards.

Use of an IEEE Standard is wholly voluntary. The IEEE disclaims liability for any personal injury, property or other damage, of any nature whatsoever, whether special, indirect, consequential, or compensatory, directly or indirectly resulting from the publication, use of, or reliance upon this, or any other IEEE Standard document.

The IEEE does not warrant or represent the accuracy or content of the material contained herein, and expressly disclaims any express or implied warranty, including any implied warranty of merchantability or fitness for a specific purpose, or that the use of the material contained herein is free from patent infringement. IEEE Standards documents are supplied “**AS IS**.”

The existence of an IEEE Standard does not imply that there are no other ways to produce, test, measure, purchase, market, or provide other goods and services related to the scope of the IEEE Standard. Furthermore, the viewpoint expressed at the time a standard is approved and issued is subject to change brought about through developments in the state of the art and comments received from users of the standard. Every IEEE Standard is subjected to review at least every five years for revision or reaffirmation. When a document is more than five years old and has not been reaffirmed, it is reasonable to conclude that its contents, although still of some value, do not wholly reflect the present state of the art. Users are cautioned to check to determine that they have the latest edition of any IEEE Standard.

In publishing and making this document available, the IEEE is not suggesting or rendering professional or other services for, or on behalf of, any person or entity. Nor is the IEEE undertaking to perform any duty owed by any other person or entity to another. Any person utilizing this, and any other IEEE Standards document, should rely upon the advice of a competent professional in determining the exercise of reasonable care in any given circumstances.

Interpretations: Occasionally questions may arise regarding the meaning of portions of standards as they relate to specific applications. When the need for interpretations is brought to the attention of IEEE, the Institute will initiate action to prepare appropriate responses. Since IEEE Standards represent a consensus of concerned interests, it is important to ensure that any interpretation has also received the concurrence of a balance of interests. For this reason, IEEE and the members of its societies and Standards Coordinating Committees are not able to provide an instant response to interpretation requests except in those cases where the matter has previously received formal consideration.

Comments for revision of IEEE Standards are welcome from any interested party, regardless of membership affiliation with IEEE. Suggestions for changes in documents should be in the form of a proposed change of text, together with appropriate supporting comments. Comments on standards and requests for interpretations should be addressed to:

Secretary, IEEE-SA Standards Board
445 Hoes Lane
Piscataway, NJ 08854
USA

Note: Attention is called to the possibility that implementation of this standard may require use of subject matter covered by patent rights. By publication of this standard, no position is taken with respect to the existence or validity of any patent rights in connection therewith. The IEEE shall not be responsible for identifying patents for which a license may be required by an IEEE standard or for conducting inquiries into the legal validity or scope of those patents that are brought to its attention.

Authorization to photocopy portions of any individual standard for internal or personal use is granted by the Institute of Electrical and Electronics Engineers, Inc., provided that the appropriate fee is paid to Copyright Clearance Center. To arrange for payment of licensing fee, please contact Copyright Clearance Center, Customer Service, 222 Rosewood Drive, Danvers, MA 01923 USA; (978) 750-8400. Permission to photocopy portions of any individual standard for educational classroom use can also be obtained through the Copyright Clearance Center.

Introduction

(This introduction is not part of IEEE Std 1526-2003, IEEE Recommended Practice for Testing the Performance of Stand-Alone Photovoltaic Systems.)

The majority of performance problems in stand-alone photovoltaic (PV) systems tend to fall into one of three areas:

- 1) Poor design or selection of inferior or inappropriate components by the system designer
- 2) Poor installation of the PV system by untrained or inexperienced system installers
- 3) Improper use or lack of maintenance of the PV system by the user

The purpose of this recommended practice is to address Item 1). In many cases, PV systems provide energy to a load as well as to a battery storage system, which powers the load at night or other times when the PV array output is insufficient. In such cases, an evaluation of system performance is heavily based on how well the PV array charges the battery and how well the battery is sized for the load.

This standard provides test methods and procedures for assessing the performance of stand-alone PV systems that include PV modules, charge controller, batteries, and loads. This standard provides type testing on a system level that can be performed at a test laboratory or by qualified personnel in the field with the appropriate test equipment. These tests are intended to evaluate the adequacy of the system design and performance claims. They require about one month to complete.

Participants

At the time this recommended practice was completed, Standards Coordinating Committee 21 (SCC21), on Fuel Cells, Photovoltaics, Dispersed Generation, and Energy Storage had the following membership:

Richard DeBlasio, *Chair*

Steve Chalmers, *Vice Chair*

T. Basso, *Secretary*

W. Bottenberg
W. Bower
J. Chamberlin
D. Dawson
W. Feero

F. Goodman
K. Hecht
B. Hornberger
Joseph L. Koepfinger
Benjamin Kroposki
R. McConnell

J. Smyth
J. Stevens
Charles Whitaker
John Wiles
John Wohlgemuth

The Stand-Alone Photovoltaic Systems Working Group of SCC21 had the following membership who participated in the preparation of this standard:

Benjamin Kroposki, *Chair*

Peter McNutt, *Secretary*

J. Anderson
G. Atmaram
P. Boulanger
Marlene Brown
P. Butler
R. Cary
Steve Chalmers
J. Chamberlin
Richard DeBlasio
J. Dunlop
S. Durand
B. Farhi

Robert L. Hammond
C. Helmke
Tom Hund
P. Hutchinson
Jason Lin
Kevin Lynn
L. Meisner
F. Metzger
M. Nispel
C. Parker
J. Phillip
J. Posbic

J. Reber
A. Rosenthal
T. Ruhlmann
E. Skolnik
E. Stein
J. Stevens
C. TerMaath
G. Tamizh-Mani
M. Thomas
Charles Whitaker
John Wiles
W. Wilson

The following members of the balloting committee voted on this recommended practice. Balloters may have voted for approval, disapproval, or abstention:

William Ackerman
Michael Behnke
Vijay Bhavaraju
Marlene Brown
Philip Capps
Steve Chalmers
Garth Corey
Michael Daugherty
Richard DeBlasio
Michael Edds
Gary Engmann
Jerry Goerz

Randall Groves
Robert L. Hammond
Steve Hogan
Tom Hund
William Kaszeta
Benjamin Kroposki
Jason Lin
Kevin Lynn
Faramarz Maghsoodlou
Walter McCannon
Peter McNutt
Robert Rallo
Blanton Robin

Charles Rogers
James Ruggieri
Steven Sano
Gary W. Scott
Craig Taborsky
Charles Whitaker
John Wiles
James Wilson
Philip Winston
John Wohlgemuth
Jane Ann Verner
Zhenxue Xu

When the IEEE-SA Standards Board approved this recommended practice on 11 September 2003, it had the following membership:

Don Wright, *Chair*
Howard M. Frazier, *Vice Chair*
Judith Gorman, *Secretary*

H. Stephen Berger
Joseph A. Bruder
Bob Davis
Richard DeBlasio
Julian Forster*
Toshio Fukuda
Arnold M. Greenspan
Raymond Hapeman

Donald N. Heirman
Laura Hitchcock
Richard H. Hulett
Anant Kumar Jain
Lowell G. Johnson
Joseph L. Koepfinger*
Tom McGean
Steve M. Mills

Daleep C. Mohla
William J. Moylan
Paul Nikolic
Gary S. Robinson
Malcolm V. Thaden
Geoffrey O. Thompson
Doug Topping
Howard L. Wolfman

*Member Emeritus

Also included are the following nonvoting IEEE-SA Standards Board liaisons:

Alan Cookson, *NIST Representative*
Satish K. Aggarwal, *NRC Representative*

Savoula Amanatidis
IEEE Standards Managing Editor

Contents

1. Overview	1
1.1 Scope.....	1
1.2 Purpose.....	1
1.3 Limitations	2
2. Definitions.....	2
3. Testing methodology	3
3.1 Testing overview.....	3
3.2 PV system and test requirements	3
3.3 Test report and documentation.....	4
4. System inspection	4
4.1 System documentation review	4
4.2 Initial system hardware inspection.....	5
5. Data acquisition system (DAS) and PV system installation.....	5
5.1 DAS specifications and installation	5
5.2 PV system installation.....	7
6. System performance tests	8
6.1 Battery preparation.....	9
6.2 Initial functional test (FT _I).....	9
6.3 Initial usable battery capacity test (UBC _I).....	9
6.4 Initial recovery test (RT _I).....	9
6.5 Final functional test (FT _F)	10
6.6 Final recovery test (RT _F)	11
6.7 Final usable battery capacity test (UBC _F)	11
6.8 Final battery charge.....	12
7. Final system inspection.....	12
7.1 System maintenance procedure review.....	12
7.2 Visual inspection.....	12
7.3 Wiring inspection.....	12
8. Array I-V curve (optional)	13
9. System pass/fail test criteria.....	13
9.1 System and load operation	13
9.2 PV array	13
9.3 Minimum UBC	13
9.4 Change in usable battery capacity.....	13

Annex A (informative) Bibliography.....	14
Annex B (informative) Sample system summary	16

