IEC TS 62257-7-4

Edition 1.0 2019-05

TECHNICAL SPECIFICATION

Recommendations for renewable energy and hybrid systems for rural electrification –
Part 7-4: Generators – Integration of solar with other forms of power generation within hybrid power systems

IEC TS 62257-7-4:2019-05(en)

IEC Central Office
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 It also gives information on projects, replaced and withdrawn publications.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.

Electropedia - www.electropedia.org
The world's leading online dictionary on electrotechnology, containing more than 22 000 terminological entries in English and French, with equivalent terms in 16 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

IEC Glossary - std.iec.ch/glossary
67 000 electrotechnical terminology entries in English and French extracted from the Terms and Definitions clause of IEC publications issued since 2002. Some entries have been collected from earlier publications of IEC TC 37, 77, 86 and CISPR.

IEC TS 62257-7-4

Edition 1.0 2019-05

TECHNICAL SPECIFICATION

Recommendations for renewable energy and hybrid systems for rural electrification –
Part 7-4: Generators – Integration of solar with other forms of power generation within hybrid power systems

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 27.160

ISBN 978-2-8322-6823-0

Warning! Make sure that you obtained this publication from an authorized distributor.

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

_____

RECOMMENDATIONS FOR RENEWABLE ENERGY AND HYBRID SYSTEMS FOR RURAL ELECTRIFICATION –

Part 7-4: Generators – Integration of solar with other forms of power generation within hybrid power systems

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) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

The main task of IEC technical committees is to prepare International Standards. In exceptional circumstances, a technical committee may propose the publication of a Technical Specification when

- the required support cannot be obtained for the publication of an International Standard, despite repeated efforts, or
- the subject is still under technical development or where, for any other reason, there is the future but no immediate possibility of an agreement on an International Standard.

Technical Specification are subject to review within three years of publication to decide whether they can be transformed into International Standards.

IEC TS 62257-7-4, which is a Technical Specification, has been prepared by IEC technical committee 82: Solar photovoltaic energy systems.

The text of this Technical Specification is based on the following documents:

Draft TS	Report on voting
82/1477/DTS	82/1545A/RVDTS

Full information on the voting for the approval of this Technical Specification can be found in the report on voting indicated in the above table.

This part of IEC 62257 is to be used in conjunction with IEC 62257 (all parts).

A list of all parts in the IEC 62257 series, published under the general title *Recommendations for renewable energy and hybrid systems for rural electrification*, can be found on the IEC website.

Future standards in this series will carry the new general title as cited above. Titles of existing standards in this series will be updated at the time of the next edition.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

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

- transformed into an International standard,
- reconfirmed,
- withdrawn,
- replaced by a revised edition, or amended.

A bilingual version of this publication may be issued at a later date.

RECOMMENDATIONS FOR RENEWABLE ENERGY AND HYBRID SYSTEMS FOR RURAL ELECTRIFICATION –

Part 7-4: Generators – Integration of solar with other forms of power generation within hybrid power systems

1 Scope

This part of IEC 62257, which is a technical specification, specifies the design and implementation of hybrid off-grid solar systems, where solar energy provides energy to a load in conjunction with other sources of energy. Such systems may or may not include an energy storage system. There are a variety of different system architectures and applications, and many ways in which these energy sources can be combined. This document distinguishes between different sorts of hybrid system applications and gives guidance on the design and integration of these systems.

It applies to single-phase and three-phase applications, and it covers situations where grid is available as an additional source of power for charging batteries and maintaining system reliability, but this document does not cover situations in which energy is fed back into a utility grid, although such systems may incidentally possess this function.

2 Normative references

The following documents are referred to in the text in such a way the 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 TS 61836, *Solar photovoltaic energy systems – Terms, definitions and symbols*

IEC TS 62257-7-2, *Recommendations for renewable energy and hybrid systems for rural electrification – Part 7-2: Generator set – Off-grid wind turbines* [1]

IEC TS 62257-7-3, *Recommendations for renewable energy and hybrid systems for rural electrification – Part 7-3: Generator set – Selection of generator sets for rural electrification systems*

IEC TS 62257-9-7, *Recommendations for renewable energy and hybrid systems for rural electrification – Part 9-7: Selection of inverters*

IEC 62509, *Battery charge controllers for photovoltaic systems – Performance and functioning*

IEC 62548, *Photovoltaic (PV) arrays – Design requirements*

IEC TS 62738, *Ground-mounted photovoltaic power plants – Design guidelines and recommendations*

[1] To be published.

3 Terms and definitions

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

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
renewable energy
REN
energy from a source that is not depleted when used

3.2
hybrid system
multi-sources system with at least two kinds of energy generation technology

3.3
storage
storage of energy produced by one of the generators of the system in a battery

3.4
DC bus
node of the electrical system to which the DC input of the battery inverter is connected to

3.5
AC bus
node of the electrical system to which the AC output of the battery inverter is connected to

3.6
black start
process of starting an electrical power supply without relying on any other external generating source

3.7
renewable fraction
fraction of energy delivered to a load that originates from renewable power sources

4 Overview

Off-grid solar hybrid systems, where a solar energy source is combined with other sources of energy such as diesel or wind, have two primary differences in functionality compared with solar-only off-grid systems. Firstly, the intermittent nature of solar can be compensated for by making use of an additional energy source. In systems with batteries, this can help to maintain the batteries charged, and can change the way the battery bank is sized with respect to the solar resource: for example a diesel generator can be relied upon to charge the batteries if they would normally have discharged after an overcast period. Secondly, the renewable aspect of the hybrid system can reduce the fuel consumption of a system which would normally be relying solely on fuel by injecting a certain amount of renewable energy into a system which is normally sustained only by diesel generators.

5 Types of hybrid systems

5.1 General

This document makes three principal distinctions according to the primary regulator of the energy output:

a) Multi-master rotating machine dominated mini-grid systems where a diesel generator creates the grid, and to which other energy sources need to synchronize.
b) Single switched master mini-grid systems with battery banks where either the battery inverter creates the grid and the other energy sources synchronize to the battery inverter output, or the diesel generator creates the grid.
c) Multi-master inverter mini-grid where certain inverters participate in the creation of the grid alongside the diesel generator.

This list is not the comprehensive range of architectures available, and there may be subtle variations upon the architectures, for example making use of other technologies such as DC coupled gensets.

These different architectures represent different renewable fractions and spatial distributions of the power generators. A rotating machine dominated mini-grid is more suitable for applications with a low renewable fraction, where renewable energy is used to offset fuel consumption in order to increase the renewable fraction and maintain constant service,

5.2 Multi-master rotating machine dominated mini-grid

5.2.1 General

A multi-master machine dominated mini-grid is a system whereby the characteristics of the grid such as voltage and frequency are created by a fuel powered rotating machine such as a diesel generator, and to which other renewable sources synchronize.

A typical application of this is for sites with a high diesel generation set demand, such as mining. The renewable energy resource is used to offset the fuel consumption of the diesel generators somewhat, but never to completely replace them. See Figure 1.

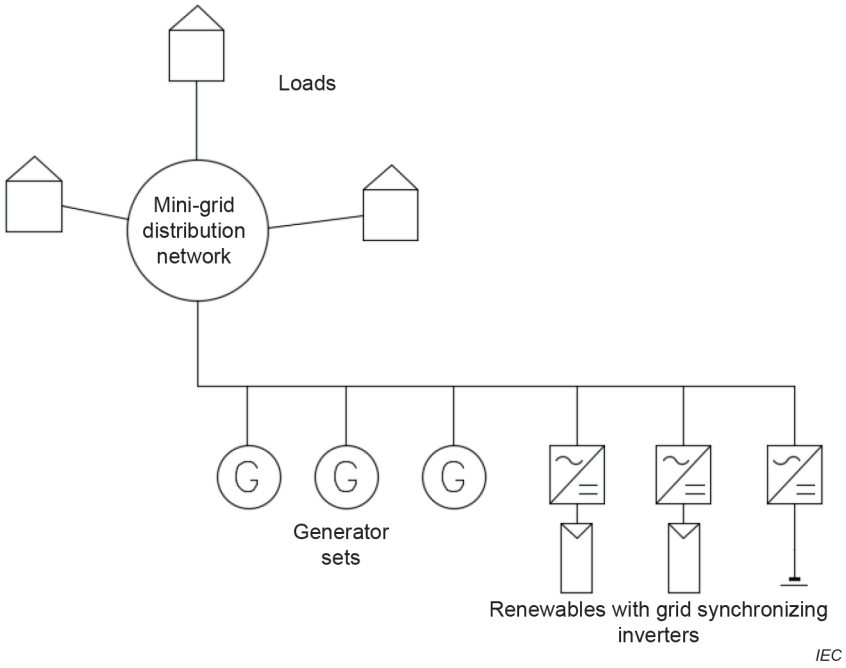

Figure 1 – Typical multi-master rotating machine dominated mini-grid architecture

5.2.2 Design

A typical arrangement is to have a diesel generator or a bank of diesel generators connected to the mini-grid distribution network, suitable sized according to the current or future predicted on-site loads. Connected in parallel to the generation sets are grid synchronizing inverters connected to a renewable energy resource, typically solar for this application. Everything is integrated together via a control mechanism, the purpose of which is ensure the correct and optimal performance of the whole system, which it does by controlling the maximum output of the inverters, and by switching diesel generators in and out according to the load being demanded.

Of particular importance is the protection of the generator sets by ensuring that under most load conditions, the generator sets are not being over-loaded or under-loaded: under-loading of a generation set can cause incomplete combustion of fuel, creating a 'wet-stacking' condition which can damage the engine. For efficient combustion the generator should typically be run at least at 40 % of its rated power but manufacturers' instructions may allow for a wider variation in power.

The other significant issue is how to maintain stability of the mini-grid in the face of rapid changes of the renewable contribution due to clouds, etc. This can be maintained by ensuring there is enough unused capacity in the generator sets (spinning reserve) that can be quickly activated in order to compensate for the drop in renewable contribution, or to integrate a small of amount of battery storage into the system.

All generating equipment shall be capable of operating at the same nominal AC voltage and frequency.

5.2.3 Design and selection of diesel generators

Detailed characteristics and design requirements for diesel generators for rural electrification, including this application, are described in IEC TS 62257-7-3.

In general, the system shall be designed in such a way that for the typical expected loads the generator sets will avoid wet-stacking, while providing some spare capacity for spinning reserve, and so typically they need to be configured so they will operate at between 40 % to

80 % of their capacity, or values that comply with manufacturer's recommendations. When the loads on site are particularly variable, then this can be ensured by having several smaller generator sets instead of one large generator set.

It should be noted that even if there are minimum recommended loadings for the generator sets, it may be acceptable to have them running under low loadings under some circumstances if it is the only way to avoid a black-out.

5.2.4 Design and selection of renewable energy component

The design of the photovoltaic array and the installation requirements are the same as described in IEC 62548. For large scale ground mounted systems, the design requirements of IEC TS 62738 may also apply.

The design and installation requirements of the wind component are to be described in IEC TS 62257-7-2.

Because the generator sets dictate the grid conditions, it is necessary to make use of inverters that can synchronize to the grid. The characteristics of suitable inverters for this application can be found in IEC TS 62257-9-7.

The percentage contribution of renewable generation at any one time should be done so that the generator sets will continue to work within the recommended minimum and maximum loading conditions.

When there are multiple gensets, it is possible to have a greater percentage of solar penetration into the system. The higher the solar penetration, the more important it is to have effective control over their energy output. It is not recommended to have a penetration percentage of greater than 60 % renewables into this type of multi-master rotating machine dominated system.

The harmonics tolerance of the diesel generators shall be checked against the harmonics of the solar and battery inverters.

5.2.5 Design and selection of batteries

Batteries may be integrated into these systems in order to reduce or eliminate the need for maintaining spinning reserve in the gensets. The batteries are connected to the AC bus using a suitable battery inverter, as discussed in IEC TS 62257-9-7 or via a hybrid inverter on the same DC bus as the PV.

The power capacity of the battery inverters should be equal to the amount of spinning reserve to be displaced. The storage capacity should be high enough to maintain a constant power through expected generation dips, or for as long as it may take non-spinning reserve (any additional gensets for example) to start-up.

5.2.6 Control system

5.2.6.1 General

The control systems to be implemented will depend upon the expected operating mode of the gensets, and of the percentage penetration of renewables into the system.

The diesel gensets can be operated in one of two ways, or a combination of both:

- Continuous operating systems – in which all the gensets are operating all of the time, and whose output is raised or lowered via droop control. For these systems it is necessary to implement a system that can measure the power flow from the generator sets with some sort of metering, and which can measure and control the power output from the renewable energy inverters.