



BSI Standards Publication

Renewable energy and hybrid systems for rural electrification

Part 7-2: Generator set — Off-grid wind turbines

National foreword

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A list of organizations represented on this committee can be obtained on request to its committee manager.

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TECHNICAL SPECIFICATION



**Recommendations for renewable energy and hybrid systems for rural electrification –
Part 7-2: Generator set – Off-grid wind turbines**



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TECHNICAL SPECIFICATION



**Recommendations for renewable energy and hybrid systems for rural electrification –
Part 7-2: Generator set – Off-grid wind turbines**

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

**RECOMMENDATIONS FOR RENEWABLE ENERGY AND
HYBRID SYSTEMS FOR RURAL ELECTRIFICATION –****Part 7-2: Generator set – Off-grid wind turbines**

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

Draft	Report on voting
82/1956/DTS	82/1995/RVDTS

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 Technical Specification 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/standardsdev/publications.

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.

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- withdrawn,
- replaced by a revised edition, or
- amended.

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INTRODUCTION

The IEC 62257 series of publications intends to provide to different players involved in rural electrification projects (such as project implementers, project contractors, project supervisors, installers, etc.) documents for the setting-up of renewable energy and hybrid systems with AC voltage below 500 V, DC voltage below 750 V and power below 100 kW.

These publications provide recommendations for:

- choosing the right system for the right place;
- designing the system;
- operating and maintaining the system.

These publications are focused only on rural electrification concentrated in, but not specific to, developing countries. They are not considered as all-inclusive of rural electrification. The publications try to promote the use of renewable energies in rural electrification. They do not deal with clean mechanism developments at this time (CO₂ emission, carbon credit, etc.). Further developments in this field could be introduced in future steps.

This consistent set of publications is best considered as a whole, with different parts corresponding to items for the safety and sustainability of systems at the lowest possible life-cycle cost. One of the main objectives of the series is to provide the minimum sufficient requirements relevant to the field of application, i.e. for small renewable energy and hybrid off-grid systems.

The purpose of this document is to provide guidance for the deployment of small wind turbines (a wind turbine with a rotor swept area smaller than or equal to 200 m², see IEC 61400-2: 2013) used in off-grid hybrid power system in rural electrification.

This document is a general introduction followed by more specific documents dedicated to the generation technologies which are the most currently used in rural electrification projects.

RECOMMENDATIONS FOR RENEWABLE ENERGY AND HYBRID SYSTEMS FOR RURAL ELECTRIFICATION –

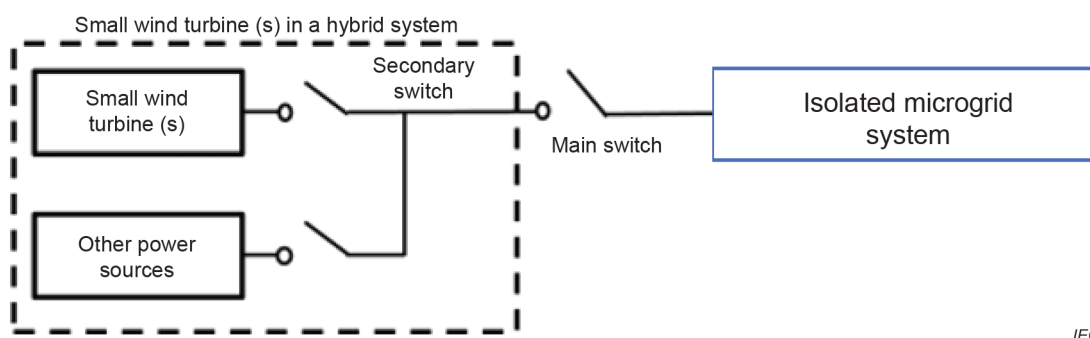
Part 7-2: Generator set – Off-grid wind turbines

1 Scope

This document applies to all small wind turbines (SWTs) with a swept area smaller than or equal to 200 m², and designed for supplying electrical power to isolated sites used in systems as described in IEC TS 62257-2.

This document is not an exhaustive resource for the design, installation, operation or maintenance of small wind turbines and wind power systems, but is more focused on recommendations to provide strategies on selection and criteria which may affect the use of a small wind power system (SWPS) in a rural electrification project.

Only the hybrid collective electrification system (microgrid, isolated microgrid) including SWT(s) is considered in this document. SWT in an isolated microgrid can be a single wind turbine or multiple wind turbines. Isolated microgrid using only wind power generation is not discussed in this document. General functional configuration of SWT(s) in an off-grid hybrid power system is shown in Figure 1.



IEC

**Figure 1 – General functional configuration of SWT(s)
in an off-grid hybrid power system**

The aim of this document is to provide users with the appropriate levels of reliability and safety of the equipment during its estimated service lifespan.

It describes the minimum safety requirements and does not claim to be an exhaustive instruction manual or design specification.

Compliance with this document does not exempt any person, organization, or corporation from the responsibility to comply with all other relevant regulations.

This document gives recommendations for the single SWT with a swept area smaller than or equal to 200 m², or multiple SWTs with other power sources of total capacity up to 100 kW in an off-grid hybrid power system.

The design life of a good quality modern wind turbine is 20 years. The real lifetime of a SWT is subjected to quite extreme loads throughout its life. This mostly depends on its designed

structure and reliability of moving parts, because the power in the wind increases with the cube of the speed.

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 60038:2009, *IEC standard voltages*
IEC 60038:2009/AMD1:2021

IEC 60287 (all parts), *Electric cables – Calculation of the current rating*

IEC 60721-2-1:2013, *Classification of environmental conditions – Part 2-1: Environmental conditions appearing in nature – Temperature and humidity*

IEC 61140, *Protection against electric shock – Common aspects for installation and equipment*

IEC 61400-2:2013, *Wind turbines – Part 2: Small wind turbines*

IEC 61400-12-1, *Wind energy generation systems – Part 12-1: Power performance measurements of electricity producing wind turbines*

IEC TS 62257-2, *Recommendations for renewable energy and hybrid systems for rural electrification – Part 2: From requirements to a range of electrification systems*

IEC TS 62257-4, *Recommendations for renewable energy and hybrid systems for rural electrification – Part 4: System selection and design*

IEC TS 62257-5, *Recommendations for renewable energy and hybrid systems for rural electrification – Part 5: Protection against electrical hazards*

IEC TS 62257-6, *Recommendations for renewable energy and hybrid systems for rural electrification – Part 6: Acceptance, operation, maintenance and replacement*

IEC TS 62257-9-1, *Recommendations for renewable energy and hybrid systems for rural electrification – Part 9-1: Integrated systems – Micropower systems*

IEC TS 62257-9-2, *Recommendations for renewable energy and hybrid systems for rural electrification – Part 9-2: Integrated systems – Microgrids*

ISO 3864-1:2011, *Graphical symbols – Safety colours and safety signs – Part 1: Design principles for safety signs and safety markings*

3 Terms and definitions

For the purposes of this document, the following terms and definitions 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

Annual Energy Production

AEP

calculated total energy that would be produced during a one-year period at an average wind speed of 5,0 m/s at hub height, assuming a Rayleigh wind speed distribution, 100 % availability, and the power curve derived from IEC 61400-12-1

SEE: 3.28.

3.2

annual average

mean value of a set of measured data of sufficient size and duration to serve as an estimate of the expected value of the quantity

3.3

annual average wind speed

V_{ave}

wind speed averaged according to the definition of annual average

3.4

brake

device capable of reducing the rotor speed or stopping rotation of a wind turbine system

3.5

collective electrification system

<isolated microgrid>

micro-power plant and micro-grid that supplies electricity to multiple consumption points using a single or multiple energy resource points

3.6

consumer label

label for the benefit of consumers consisting of two parts: the label itself, and a test summary report made available by a web site

3.7

control system

sub-system that receives information about the condition of the wind turbine system and/or its environment and adjusts the turbine in order to maintain it within its operating limits

3.8

start-up wind speed

wind speed at which the rotor first begins to turn after being at rest once spinning, wind turbine rotors can coast to lower wind speeds than those necessary to start the rotor revolving

3.9

cut-in wind speed

V_{in}

lowest mean hub height wind speed bin value at which the wind turbine system produces a net positive power output. The turbine does not produce power between start up wind speed and cut in wind speed.

3.10

cut-out wind speed

V_{out}

highest mean wind speed at hub height at which the wind turbine system is designed to produce power

3.11

downwind

in the main direction of wind flow

3.12

emergency shutdown

rapid shutdown of the wind turbine system triggered by a protection system or by manual intervention

3.13

external condition

factor affecting the operation of a wind turbine system including the environmental conditions (temperature, snow, ice, etc.) and the electrical network conditions that are not part of the wind turbine system

3.14

extreme wind speed

highest average wind speed, averaged over t seconds, that is likely to be experienced within a specified time period (recurrence period) of T years

3.15

fail-safe

design property of an item which prevents its failures from resulting in critical faults

3.16

hybrid power system

HPS

power system including generators from different technologies

3.17

horizontal axis wind turbine

HAWT

type of wind turbine in which the axis of the rotor's rotation is nominally parallel to the horizontal ground surface

3.18

hub

fixture for attaching the blades or blade assembly to the rotor shaft of a wind turbine system

3.19

hub height

height of the geometric center of the swept area of the wind turbine rotor above the terrain surface

3.20

mean wind speed

statistical mean of the instantaneous value of the wind speed averaged over a given time period which can vary from a few seconds to 1 year

Note 1 to entry: Though wind speed varies over a continuum, measurements used to develop power curves group power measurements into separate discrete registers or bins, for wind speed in m/s, typically 0,5m/s wide. The 5 m/s bin, for example, would represent winds from 4,75 to 5,25 m/s.

3.21

nacelle

housing which contains the drivetrain and other elements on top of a horizontal axis wind turbine tower

3.22**noise label**

defined graphical and textual representation of the acoustic noise data pertaining to a small wind turbine system

3.23**overspeed control**

action of a control system, or part of such system, which prevents excessive rotor speed

3.24**power form and voltage**

physical characteristics which describe the form in which power produced by the wind turbine system is made deliverable to the load (e.g. 230 V AC, 50 Hz, 1 ph; or e.g. 48 V DC)

3.25**protection system**

system which ensures that a wind turbine generator system remains within the design limits

3.26**rated power**

maximum continuous electrical output power which a wind turbine system is designed to achieve at the connection facilities under normal operation

Note 1 to entry: The rated power of SWT is its output at 11 m/s at standard sea-level condition.

Rated power of SWT varies roughly proportionally to the swept area of the rotor. Blade design and technology developments are therefore one of the keys to increasing wind turbine capacity output. By doubling the rotor diameter, the swept area and therefore power output is increased by a factor of four.

3.27**rated wind speed**

wind speed at which a wind turbine system's rated power is achieved. The distribution depends on one adjustable parameter – the scale parameter, which controls the average wind speed.

3.28**maximum design wind speed**

highest allowable wind speed for turbine operations

Note 1 to entry: It is expressed in m/s.

3.29**swept area**

projected area perpendicular to the wind direction that a rotor will describe during one complete rotation

Note 1 to entry: It is expressed in m².

3.30**Rayleigh distribution**

probability distribution function often used for wind speeds

3.31**reference annual energy**

calculated total energy that would be produced during a one-year period at an average wind speed of 5,0 m/s at hub height, assuming a Rayleigh wind speed distribution, 100 % availability, and the power curve derived from IEC 61400-12-1 (where it is referred to as Annual Energy Production (AEP))

Note 1 to entry: The AEP from IEC 61400-12-1 is either the "AEP-measured" or the "AEP-extrapolated", and is either "sea-level normalised" or "site-specific".

Note 2 to entry: In this document reference annual energy is AEP-measured and sea-level normalised.

Note 3 to entry: The reference annual energy is defined for the purposes of comparing wind turbine systems.

3.32 reference wind speed

V_{ref}

basic parameter for wind speed used for defining SWT classes

Note 1 to entry: Other design related climatic parameters are derived from the reference wind speed and other basic SWT class parameters.

Note 2 to entry: A turbine designed for a SWT class with a reference wind speed, V_{ref} , is designed to withstand climates for which the extreme 10 min average wind speed with a recurrence period of 50 years at turbine hub height is lower than or equal to V_{ref} .

3.33 resonance

phenomenon appearing in an oscillating system, in which the period of a forced oscillation is very close to that of free oscillation

3.34 rotor centre

geometric centre of the wind turbine rotor

3.35 rotor speed

rotational speed of a wind turbine rotor about its axis

3.36 scheduled maintenance

preventive maintenance carried out in accordance with an established time schedule

3.37 Small Wind Power System

SWPS

includes the wind turbine itself including support structures, the turbine controller, the charge controller / inverter (if required), wiring and disconnects, the installation and operation manual(s) and other documentation

3.38 Small Wind Turbine

SWT

wind turbine with a rotor swept area smaller than or equal to 200 m² (IEC 61400-2)

3.39 swept area

projected area perpendicular to the wind direction that a rotor will describe during one complete rotation

3.40 turbulence intensity

ratio of the wind speed standard deviation to the mean wind speed, determined from the same set of measured data samples of wind speed, and taken over a specified period of time

3.41 upwind

in the direction opposite to the main direction of wind flow

3.42**Vertical Axis Wind Turbine**

VAWT

wind turbine system whose rotor axis is substantially perpendicular to the wind flow

3.43**Weibull distribution**

probability distribution function often used for wind speeds

3.44**wind speed distribution**

probability distribution function, used to describe the distribution of wind speeds over an extended period of time

3.45**wind shear**

variation of wind speed across a plane perpendicular to the wind direction

3.46**wind speed**

velocity of air at a specified point in space wind profile

3.47**wind profile**

wind shear law mathematical expression for assumed wind speed variation with height above ground

Note 1 to entry: Commonly used profiles are the logarithmic profile (1) or the power law profile (2).

$$V_{(z)} = V_{(z_r)} \times \frac{\ln(z/z_0)}{\ln(z_r/z_0)} \quad (1)$$

$$V_{(z)} = V_{(z_r)} \times \left(\frac{z}{z_r}\right)^\alpha \quad (2)$$

where

 $V_{(z)}$ is the wind speed at height z ; z is the height above ground; z_r is a reference height above ground used for fitting the profile; z_0 is the roughness length; α is the wind shear (or power law) exponent.**3.48****yaw mechanism**

yaw system is the component responsible for the orientation of the wind turbine rotor towards the wind

4 Symbols and abbreviated terms**4.1 Abbreviated terms**

AEP	annual energy production
EHS	extra high strength
HAWT	horizontal axis wind turbine
HPS	hybrid power system
O&M	operation and maintenance
QC	quality control

RPM	revolution(s) per minute
SWPS	small wind power system
SWT	small wind turbines
VAWT	vertical-Axis wind turbine
VOM	Volt-Ohm-Milliammeter, another name for a multimeter
WT	wind turbines

4.2 Symbols

C_p	power coefficient, a measure of wind turbine efficiency
D	diameter of rotor
H_0	reference height
H	height
K_i	capacity descent factor
P	rated capacity of an electronic component at normal conditions
P_i	equivalent capacity at high elevation
V	voltage
V_0	measured wind speed at the height H_0
α	wind shear exponent

5 Wind turbine (WT)

5.1 Types of wind turbines

5.1.1 Horizontal axis wind turbine (HAWT)

HAWT mainly consists of the following parts: rotor (blades), generator, speed regulating mechanism, direction regulating mechanism (yaw system), brake mechanism and tower. Normally HAWT has three blades, but can also have two blades or multiple blades. Typically a small HAWT uses a tail vane assembly for its direction regulating mechanism, while for a large HAWT, a transmission device consisting of a sensor element and a servo motor is used. Figure 2a) is tail vane direction regulating type, or called passive yaw regulation type, which is widely used in small wind turbines; while Figure 2b) is electrical transmission device direction regulating type, or called active yaw regulating type, which is used for all large wind turbines. Figure 3 shows examples of rotors with different number of blades. This document applies to designs with any number of blades.