IEC TS 61400-30

Edition 1.0 2023-09

TECHNICAL SPECIFICATION

colour inside

Wind energy generation systems –
Part 30: Safety of wind turbine generators – General principles for design

IEC TS 61400-30:2023-09(en)

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 It also gives information on projects, replaced and withdrawn publications.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. 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 22 300 terminological entries in English and French, with equivalent terms in 19 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

IEC TS 61400-30

Edition 1.0 2023-09

TECHNICAL SPECIFICATION

colour inside

Wind energy generation systems –
Part 30: Safety of wind turbine generators – General principles for design

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 27.180 ISBN 978-2-8322-7439-2

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

____

WIND ENERGY GENERATION SYSTEMS –

Part 30: Safety of wind turbine generators – General principles for design

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 TS 61400-30 has been prepared by IEC technical committee 88: Wind energy generation systems. It is a Technical Specification.

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

Draft	Report on voting
88/910/DTS	88/935A/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/publications.

A list of all parts in the IEC 61400 series, published under the general title *Wind energy generation systems*, 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.

IMPORTANT – The "colour inside" logo on the cover page of this document indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

WIND ENERGY GENERATION SYSTEMS –

Part 30: Safety of wind turbine generators – General principles for design

1 Scope

This part of IEC 61400, which is a Technical Specification, specifies the essential health and safety requirements related to the design of wind turbines with horizontal axes with the exception of those included in the scope of IEC 61400-2.

For other wind turbine concepts such as vertical axes, floating, or smaller turbines (see IEC 61400-2), the principles of this document are valid, however they are adjusted to the actual concept.

This document focuses on requirements for safe operation, inspection, maintenance, installation and decommissioning.

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 60073, *Basic and safety principles for man-machine interface, marking and identification – Coding principles for indicators and actuators*

IEC 60204-1:2016, *Safety of machinery - Electrical equipment of machines - Part 1: General requirements*

IEC 60204-11, *Safety of machinery – Electrical equipment of machines – Part 11: Requirements for equipment for voltages above 1 000 V AC or 1 500 V DC and not exceeding 36 kV*

IEC 60364-4-41, *Low-voltage electrical installations – Part 4-41: Protection for safety – Protection against electric shock*

IEC 60529, *Degrees of protection provided by enclosures (IP Code)*

IEC 60695-11-10, *Fire hazard testing – Part 11-10: Test flames – 50 W horizontal and vertical flame test methods*

IEC 60950-1, *Information technology equipment − Safety − Part 1: General requirements*

IEC 61000-6-2, *Electromagnetic compatibility (EMC) – Part 6-2: Generic standards – Immunity standard for industrial environments*

IEC 61000-6-4, *Electromagnetic compatibility (EMC) – Part 6-4: Generic standards – Emission standard for industrial environments*

IEC 61310-1, *Safety of machinery – Indication, marking and actuation – Part 1: Requirements for visual, acoustic and tactile signals*

IEC 61400-1:2019, *Wind energy generation systems – Part 1: Design requirements*

IEC 61400-3-1, *Wind energy generation systems – Part 3-1: Design requirements for fixed offshore wind turbines*

IEC TS 61400-3-2, *Wind energy generation systems – Part 3-2: Design requirements for floating offshore wind turbines*

IEC 61400-24, *Wind energy generation systems – Part 24: Lightning protection*

IEC 61439-1, *Low-voltage switchgear and controlgear assemblies – Part 1: General rules*

IEC 61439-2, *Low-voltage switchgear and controlgear assemblies – Part 2: Power switchgear and controlgear assemblies*

IEC 61508 (all parts), *Functional safety of electrical/electronic/programmable electronic safety-related systems*

IEC 61936-1:2021, *Power installations exceeding 1 kV AC and 1,5 kV DC − Part 1: AC*

IEC 62040 (all parts), *Uninterruptible power systems (UPS) – Part 1: Safety requirements*

IEC 62061:2021, *Safety of machinery – Functional safety of safety-related control systems*

IEC 62271-200, *High-voltage switchgear and controlgear – Part 200: AC metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV*

IEC 62485 (all parts), *Safety requirements for secondary batteries and battery installations*

ISO 3864 (all parts), *Graphical symbols – Safety colours and safety signs*

ISO 4413, *Hydraulic fluid power – General rules and safety requirements for systems and their components*

ISO 4414, *Pneumatic fluid power – General rules and safety requirements for systems and their components*

ISO 7010, *Graphical symbols – Safety colours and safety signs – Registered safety signs*

ISO 7250 (all parts), *Basic human body measurements for technological design*

ISO 9355 (all parts), *Ergonomic requirements for the design of displays and control actuators*

ISO 11228 (all parts), *Ergonomics – Manual handling*

ISO/TR 11688-1, *Acoustics – Recommended practice for the design of low-noise machinery and equipment – Part 1: Planning*

ISO/TR 11688-2, *Acoustics − Recommended practice for the design of low-noise machinery and equipment − Part 2: Introduction to the physics of low-noise design*

ISO 12100:2010, *Safety of machinery – General principles for design – Risk assessment and risk reduction*

ISO 13732-1, *Ergonomics of the thermal environment – Methods for the assessment of human responses to contact with surfaces – Part 1: Hot surfaces*

ISO 13732-3, *Ergonomics of the thermal environment – Methods for the assessment of human responses to contact with surfaces – Part 3: Cold surfaces*

ISO 13849-1:2015[1], *Safety of machinery – Safety-related parts of control systems – Part 1: General principles for design*

ISO 13849 (all parts), *Safety of machinery – Safety-related parts of control systems*

ISO 13850:2015, *Safety of machinery – Emergency stop function – Principles for design*

ISO 13854, *Safety of machinery – Minimum gaps to avoid crushing of parts of the human body*

ISO 13857, *Safety of machinery – Safety distances to prevent hazard zones being reached by upper and lower limbs*

ISO 14118, *Safety of machinery – Prevention of unexpected start-up*

ISO 14119, *Safety of machinery – Interlocking devices associated with guards – Principles for design and selection*

ISO 14120, *Safety of machinery – Guards – General requirements for the design and construction of fixed and movable guards*

ISO 14122-1, *Safety of machinery – Permanent means of access to machinery – Part 1: Choice of fixed means and general requirements of access*

ISO 14122-2, *Safety of machinery – Permanent means of access to machinery – Part 2: Working platforms and walkways*

ISO 14122-3, *Safety of machinery – Permanent means of access to machinery – Part 3: Stairs, stepladders and guard-rails*

ISO 14122-4:2016, *Safety of machinery – Permanent means of access to machinery – Part 4: Fixed ladders*

ISO 14567, *Personal protective equipment for protection against falls from a height – Single-point anchor devices*

ISO 15534 (all parts), *Ergonomic design for the safety of machinery*

ISO 19353:2019, *Safety of machinery – Fire prevention and fire protection*

ISO 20607, *Safety of machinery – Instruction handbook – General drafting principles*

EN 353-1, *Personal fall protection equipment – Guided type fall arresters including an anchor line – Part 1: Guided type fall arresters including a rigid anchor line*

EN 353-2, *Personal protective equipment against falls from a height – Part 2: Guided type fall arresters including a flexible anchor line*

[1] Withdrawn.

EN 1005 (all parts), *Safety of machinery – Human physical performance*

EN 12198 (all parts), *Safety of machinery – Assessment and reduction of risks arising from radiation emitted by machinery*

EN 12464-1, *Light and lighting – Lighting of workplaces – Part 1: Indoor workplaces*

EN 16165:2021, *Determination of slip resistance of pedestrian surfaces – Methods of evaluation*

CIE 97:2005, *Guide on the maintenance of indoor electric lighting systems*

ICAO Annex 14. 9th Edition, July 2022

3 Terms and definitions

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

3.1
hazard
potential source of harm

[SOURCE: ISO/IEC Guide 51:2014, 3.2]

3.2
significant hazard
hazard which has been identified as relevant and which requires specific action by the designer to eliminate or to reduce the risk according to the risk assessment

Note 1 to entry: A relevant hazard is identified as the result of one step of the process described in Clause 5.

[SOURCE: ISO 12100:2010, 3.8, modified – Note 1 to entry has been changed.]

3.3
risk
combination of the probability of occurrence of harm (physical injury or damage to health) and the severity of that harm

[SOURCE: ISO 12100:2010, 3.12, modified – "(physical injury or damage to health)" has been added.]

3.4
intended use
use of a machine in accordance with the information for use provided in the instructions

[SOURCE: ISO 12100:2010, 3.23]

3.5
protective measure
measure intended to achieve adequate risk reduction, implemented:

- by the designer (inherently safe design, safeguarding and complementary protective measures, information for use) and/or
- by the user (organization: safe working procedures, supervision, permit-to-work systems; provision and use of additional safeguards; use of personal protective equipment; training)

[SOURCE: ISO 12100:2010, 3.19]

3.6
environment
surroundings in which a product or system exists, including air, water, land, natural resources, flora, fauna, humans, and their interrelation

[SOURCE: IEC Guide 109:2012, 3.3]

3.7
environmental conditions
characteristics of the environment (wind, altitude, temperature, humidity, etc.) which may affect the wind turbine behaviour

[SOURCE: IEC 61400-1:2019, 3.17]

3.8
external conditions
factors affecting operation of a wind turbine, including the environmental conditions (temperature, snow, ice, etc.) and the electrical network conditions

[SOURCE: IEC 61400-1:2019, 3.18]

3.9
anchorage
for a personal protective equipment, structure or part of structure which can support load from fall protection or rescue systems

3.10
anchor point
component or sub-system that functions as an interface between the anchorage and a fall protection, work positioning, rope access or rescue system for the purpose of coupling the system to the anchorage

Note 1 to entry: It can be intended or not intended to be removable.

3.11
limited free fall
limited distance that can be compared with "fall on the actual level" i.e., a trip or slip where person is falling onto the surface/ground on which he or she was standing/walking ~ a fall at same level

Note 1 to entry: "Limited free fall" distance is set to maximum 0,5 m.

3.12
fall protection
system (including all components) a worker/technician uses to provide protection from falling and/or to safely arrest and mitigate the impact of a worker/technician's fall if one occurs

Note 1 to entry: Examples of personal fall protection systems include personal fall arrest systems, positioning systems and travel restraint systems.

3.13
fall arrest
system used to arrest a worker/technician in a fall from a walking-working surface, consisting of a body harness, anchorage and connector

Note 1 to entry: The means of connection can include a lanyard, deceleration device, lifeline, or a suitable combination of these.

3.14
work positioning
system of equipment and connectors that, when used with a body harness or body belt, allows a worker/technician to be supported on an elevated vertical surface, such as a wall or windowsill, and work with both hands free

Note 1 to entry: Positioning systems also are called "positioning system devices" and "work-positioning equipment."

3.15
fall/travel restraint
combination of an anchorage, anchor point, lanyard (or other means of connection) and body support that a worker/technician uses to eliminate the possibility of a worker/technician going over the edge of a walking-working surface

3.16
evacuation
in a wind turbine, process of leaving the wind turbine in an emergency situation, when persons are able to use the predefined access route

Note 1 to entry: Successful evacuation will result in personnel being transferred to a place of safety.

3.17
escape
in a wind turbine, process of leaving the wind turbine in an emergency situation when the persons are unable to use the predefined access route.

Note 1 to entry: It is a last resort method of getting out of the wind turbine.

3.18
rescue
in a wind turbine, operation to retrieve an injured person out of the turbine or a person unable to self-rescue to a place of safety

3.19
rescue equipment
in a wind turbine, system of equipment, anchorage and connectors that, when used with a body harness, rescue harness or body belt, allows a worker/technician to be rescued by getting descended from an elevated vertical surface, such as a machine, structure, etc.

3.20
place of safety
means an onshore or safe offshore location or vessel where medical treatment and other facilities for the care of survivors are available

3.21
place of temporary safety
place where a person is not exposed to the fire or the fire effects (e.g., such as smoke or falling objects)

Note 1 to entry: It can be a refuge inside the wind turbine or the sea.

3.22
available safe egress time
ASET
amount of time from fire ignition to the development of untenable conditions

3.23
required safe egress time
RSET
amount of time, measured from fire ignition that required for the last person to evacuate to a place of safety or place of temporary safety

3.24
control functions
functions of the control system that based on information about the condition of the wind turbine and/or its environment, adjust the wind turbine in order to maintain it within the operating limits defined by the wind turbine designer

3.25
control system
system implementing the wind turbine control, protection and safety functions, including sensors, logic elements, actuators, communication networks and power supplies

Note 1 to entry: The intent of the control system is to control operation of the wind turbine by active and passive means and keep the operating parameters within the design limits.

3.26
control station
location inside or outside the wind turbine where a control panel, a control device or arrangement of control panels and control devices or other means to manually control the wind turbine is located

3.27
design limits
maximum or minimum values used in a design

3.28
substructure
part of an offshore wind turbine support structure which transfers the loads acting on the structure into the seabed

3.29
boat landing
area where access from the vessel takes place, i.e., the part of the access ladder where the fender tubes are placed

3.30
performance level
PL
discrete level used to specify the ability of safety-related parts of control systems to perform a safety function under foreseeable conditions

3.31
required performance level
PL_R
performance level (PL) applied in order to achieve the required risk reduction for each safety function

[SOURCE: ISO 13849-1:2015, 3.1.24]

3.32
restricted space
enclosed or partially enclosed space, not intended for continuous human occupancy that has a restricted, limited, or impeded means of entry or exit because of its construction

Note 1 to entry: It can be thought of as a work area in which the only hazard is the difficulty of getting into or out of the space. All other hazards are either non-existent or have been eliminated or controlled.

3.33
confined space
enclosed or partially enclosed space that is not designed or intended for continuous human occupancy, with a restricted, limited, or impeded means of entry and exit because of its construction, and which can become hazardous to a person entering it, due to either an atmosphere that is or can be injurious (by oxygen deficiency or flammability, explosivity or toxicity), or due to an activity which can produce adverse or harmful consequences

3.34
equipment
single apparatus or set of devices or apparatuses, or the set of main devices of an installation, or all devices necessary to perform a specific task

3.35
safe state
condition of the wind turbine with an acceptable level of residual risks according to the risk assessment

3.36
safety-related part of a control system
SRP/CS
part of a control system that responds to safety-related input signals and generates safety-related output signals

[SOURCE: ISO 13849-1:2015, 3.1.1, modified – Notes to entry have been deleted]

3.37
safety functions
in wind turbine, functions of the control system whose failure can result in an immediate increase of the risk(s)

3.38
safety integrity level
SIL
discrete level (one out of a possible three) for describing the capability to perform a safety function where safety integrity level three has the highest level of safety integrity and safety integrity level one has the lowest

[SOURCE: IEC 62061:2021, 3.2.24]

3.39
standstill
condition of a wind turbine that is stopped

[SOURCE: IEC 61400-1:2019, 3.54]

3.40
wind turbine
<wind turbine> generator system which converts the kinetic wind energy into electric energy

[SOURCE: IEC 61400-1:2019, 3.71, modified – "generator system" has been deleted from the term, generator has been added to "system" in the definition.]

3.41
rest platform
in wind turbines, horizontal platform, which allows more than one person to rest (standing and sitting)

3.42
moveable rest landing
in wind turbines, small horizontal platform where a single person can rest (standing) with both feet fully supported

3.43
service lift
machine with a fully enclosed load carrying unit including floor, walls, doors and roof which is guided and intended for transport of persons and materials between different levels

4 Principal elements

4.1 General

The wind turbine shall be designed according to the principles in ISO 12100 for the significant hazards as a minimum as identified in Annex A of the present document.

A wind turbine shall be designed and constructed so that it can be installed, operated, adjusted, maintained and decommissioned in a safe way.

Identification of the essential health and safety requirements, their risk assessment and risk reduction shall be done in accordance with ISO 12100.

The measures adopted to fulfil the essential health and safety requirements shall be applied with the following principles in the order given:

- eliminate the risks;
- take the necessary protective measures in relation to risks that cannot be eliminated;
- inform users of the residual risks by means of signs or instructions.

This document shall be used together with the mentioned IEC and ISO standards in Clause 2.

The design of the wind turbine shall consider intended use and reasonably foreseeable misuse during its lifecycle as defined in ISO 12100.

4.2 Significant hazards

The limitation of use for machinery as wind turbine shall be done as specified in ISO 12100:2010, 5.3. An informative list of relevant factors for consideration when preparing risk assessment specific for wind turbine can be found in Annex A.

4.3 Frequency of exposure

When deciding the frequency of exposure to a specific hazard in the wind turbine and determining the required performance level or safety integrity level of a safety function, ISO 12100:2010, Clause 5 shall be followed.

If the frequency is classified as high or low, ISO 13849-1:2015, A.2.2 can be used as a guide.

For the estimation of the frequency for each single safety function, ISO 13849-1:2015, A.2.2 and IEC 62061:2021 can be used for guidance.

5 Control systems

5.1 General

The safety of the wind turbine shall be governed by a control system that meets the requirements of IEC 61400-1:2019, Clause 8.

Whereas the scope of IEC 61400-1:2019, Clause 8 is limited to ensuring that the control system provides an appropriate level of protection against structural failure of the turbine main components, this document takes more account of personal safety aspects.

The emergency stop functions shall have priority over all other functions and operations in all operating modes of the machine in accordance with ISO 13850.

The control, protection and safety functions shall be designed in such a way that safety is retained in all operating modes. ISO 13849-1:2015, 5.1 items b), g) and i) or IEC 62061:2021, 5.2.3 can be used for guidance.

The control system shall be designed in such a way that:

- it can withstand all reasonably foreseeable operating conditions that can occur in a wind turbine including internal and external conditions;
- its behaviour including faults and errors does not compromise safety, in accordance with IEC 61400-1:2019, 8.4;
- reasonably foreseeable misuse does not lead to a hazardous situation.

5.2 Control devices

Any manual control device, e.g., Human Machine Interface (HMI), shall be clearly visible and identifiable by appropriate marking in accordance with standards such as IEC 60073. If there are several control devices for manual intervention of a system, it shall not be possible to use more than one at the same time for that system. This does not apply to emergency stop devices. Further, it shall be possible to lock a device for use such that no other device can interfere or even override the control (e.g., physical mode selector, software mode selector, pad lock system, key switch).

It shall be possible to control operation of the wind turbine through a control device in the vicinity of the main entrance to a wind turbine, e.g., at the tower bottom and in the nacelle for wind turbines with access via helicopter.

5.3 Operating modes

A wind turbine control system shall have a number of well-defined operating modes (manned/unmanned), for example:

- operation mode (unmanned): wind turbine is in power production, with no personnel present in the wind turbine,
- maintenance mode (manned): wind turbine stopped for troubleshooting, maintenance, or repairs,
- exception (manned during operation): extraordinary situations where it is necessary to be present in the wind turbine for a short period of time and for a specific task.

The mode selection shall be governed by a selector, which can be effectively locked in each position corresponding with a single mode.

None of these modes shall compromise the performance of the safety functions.

A wind turbine with automatic restart capability shall be provided with a means to locally disable the automatic restart function of the wind turbine.

For manual, automatic and remote restart requirements, reference is made to IEC 61400-1:2019, 8.7.

Certain operations may only be possible in certain modes. There shall be at least one mode prohibiting remote control actions. While in this mode, it shall not be possible to:

- leave this mode automatically,
- leave this mode through input from an external operating position,
- control the turbine remotely.

Remote control may be possible if this is temporary granted by the personnel on site.

Measures shall be in place to inform personnel in case of external conditions, e.g., wind speed, approaching the limit for safe maintenance.

5.4 Safety functions

The identification of safety functions shall be based on a risk assessment/risk reduction process according to ISO 12100. A list of potential hazards relevant for wind turbines can be found in Annex A.

The allocation of risk reduction to the control system of the wind turbine shall be done only when risk elimination or reduction by inherently safe design measures are determined to be not applicable /sufficient or not reasonably practicable.

If risk reduction depends on the control system, the design of safety-related parts of the control system shall be in accordance with the ISO 13849 series and/or IEC 62061 and/or the IEC 61508 series.

NOTE Guidance can be found in ISO/TR 22100-2.

5.5 Emergency stop

The emergency stop design and function shall comply with ISO 13850 and IEC 61400-1:2019, 8.6, giving guidance on e.g., emergency stop device availability, location, choice of stop functionality and reset behaviour.

Based on the outcome of a risk assessment, it shall be specified which stop category (0 or 1) is chosen. Further, any functionality required from the control system when the emergency stop device is activated shall be clearly specified. This is particularly important when stop category 1 (controlled stop) is chosen. Guidance on choice of the categories can be found also in IEC 60204-1:2016, 9.2.3.4.2.

The state of the wind turbine before and after the activation of the emergency stop function shall be defined by the designer.

Additionally, the following requirements apply for a wind turbine:

- An emergency stop device shall be located:
  – at each operator control station, except where the risk assessment indicates that this is not necessary;

  - at other locations, as determined by the risk assessment, e.g., at nacelle, hub, tower bottom, yaw access ladder, at interface between lift and platforms.
- Separately manoeuvred systems, for example service lifts, cranes and winches, shall have their own emergency stop devices which shall only affect those systems.

Any system that will foreseeable be used for the safety of personnel shall not be affected; for example, ventilation system, communication system, fire extinguishing system or lifts used for personal transport (subject to risk assessment).

5.6 Failure of external power supply

For the event "failure of external power supply" during maintenance mode, a safe wind turbine behaviour/reaction shall be ensured, considering all possible scenarios such as:

- power loss while working in the wind turbine,
- power is restored while working in the wind turbine,
- working in a wind turbine without power.

In case of a loss of external power supply, the control system shall set the wind turbine into a safe state.

After return of external power supply, the wind turbine or the affected sub-system shall maintain a safe state. Loss of external power supply can affect, for example, electrical, mechanical, or hydraulic systems.

If safe state requires complete standstill of the rotor in case of failure of the external power supply and is dependent on the mechanical brake, the brake shall be able to keep the rotor in this position for the defined wind conditions for service for at least one hour after the brake is applied in accordance with IEC 61400-1:2019, 8.8.

During periods of grid loss, it shall be possible to apply the brake by either an auxiliary power supply or by manual operation.

NOTE 1 Considerations for emergency stops are provided by ISO 13850:2015, 4.1.1.2.

NOTE 2 Wind speed limits are assigned in accordance with the design load cases in IEC 61400-1:2019.

6 Isolation of energy sources

The design of the wind turbine shall enable safe and complete energy isolation of all hazardous energy (any type of energy that, if released unexpectedly, can cause an injury or damage, e.g. kinetic and potential such as mechanical, electrical, hydraulic and pneumatic energy).

The design shall ensure a safe application of an isolation sequence in accordance with the requirements of ISO 12100 and ISO 14118.

It shall be necessary in some energy isolation activities to also test and ensure de-energization (try-out) as part of this sequence.

The wind turbine shall be provided with isolation devices (per type of energy) following the following minimum requirements:

- minimum label for the isolation device: name and function (i.e., identification of the circuit or system which it controls);
- be located as close as practicable to the circuit or equipment to be isolated;

- be designed such that the individual responsible for switching of and locking off the energy source is protected from contact with energized electrical components, arc flash hazards and other energy hazard;
- be capable of being securely locked out individually; and be capable of accepting systems to apply multiple locks.

The wind turbine designer shall develop energy isolation procedures per component, describing the sequence of safe isolation indicating: the type of energy (kinetic and potential), the magnitude, the isolation device and the location to verify de-energization.

The wind turbine shall be provided with systems for safe discharging of energy in storing elements such as:

- hydraulic: pressure in lines,
- mechanical: springs,
- electric: capacitors.

7 Electrical systems

7.1 General requirements

All electrical components in the wind turbine shall be designed and constructed to enable safe operation, in accordance with ISO 12100 and IEC 61400-1.

These are some general requirements for the networks and electrical equipment installed on a wind turbine:

- It shall be equipped with electrically coordinated automatic protective devices to interrupt inadvertent releases of energy.
- It shall be constructed or protected to prevent danger arising from:
  - mechanical damage;
  - the effects of weather, natural hazards, temperature, or pressure;
  - the effects of wet, dirty, dusty, or corrosive conditions.
- All internal networks are fitted with suitable earthing arrangements, and there shall be a process in place to check the earthing system periodically.
- All the electrical equipment shall have sufficient electrical rating to withstand short-circuits taking into account the relevant fault level.
- All the electrical equipment shall have sufficient electrical rating taking into account the generated current and voltage for the designed lifetime.
- The wind turbine shall have digital and/or printed electrical drawings easily accessible at the site of work (e.g., tower entrance). Moreover, all electrical cabinets shall be properly labelled to track the eventual design modifications and to enable identification of the specific electrical drawing revision to be used.
- All electrical equipment shall be labelled to enable identification of individual circuits and isolation devices.
- Enclosures containing power circuits with exposed live parts[2] shall provide a means of isolation of energized circuits from outside the enclosures.

[2] Enclosures are considered to have exposed live parts in cases where the level of ingress protection while opened does not fulfil IP2X as defined by IEC 60529. Alternative methods of classifying the presence of exposed live parts may be used where suitable.

- Work areas containing exposed live parts or transformers (e.g., transformer room in the tower/nacelle of wind turbine) shall be provided with an interlock system, exchange key system or equivalent to prevent the door from opening when equipment is still energized.
- There shall be a clear process defined, including the necessary tooling, to access and maintain all the electrical equipment in the wind turbine. In line with this requirement, all the equipment classified as high voltage[3] shall be identified.
- When high voltage and low voltage electrical cables are running in proximity to each other (e.g., cable loop), they shall have appropriate insulation, separation or shielding not to affect each other.
- The mechanical properties of electrical cables and their fixings shall withstand the expected mechanical forces from cable twist, the cable weight and forces in case of a short-circuit.

7.2 Protection provided by enclosures

IEC 60529 requirements shall be fulfilled.

The risk of contact with live parts shall be prevented by the use of enclosures or barriers.

Live components inside cabinets shall be provided with protection against direct contact in accordance with IEC 60204-1:2016, 6.2.2:

- directly accessible components IP2X or IPXXB,
- live parts provided by top surfaces or openings IP4Xor IPXXD.

Protection provided by barriers shall be according to IEC 60364-4-41.

7.3 High voltage installation

The voltage thresholds which classify an installation as high voltage (HV) can differ depending on regional definitions. The standards applicable to electrical installations shall be determined based upon the voltage of the installations and the voltage thresholds defined in the scope of those standards.

- Electrical installations exceeding 1 kV AC, or 1,5 kV DC shall be designed according to IEC 60204-11, IEC 61936-1 and IEC 62271-200.

An interlock system shall prevent opening the HV transformer enclosures before de-energizing the HV transformer breaker and earthing the HV transformer cable at the HV switchgear.

The enclosures of HV areas with exposed live parts shall be designed to fulfil at least minimum required protective clearance and ingress protection according to IEC 61936-1.

The HV part shall have provisions to isolate and ground the HV system, so it is not affected by auxiliary power in case of connection of an external energy source.

HV cables running outside the HV enclosures shall meet the protection against direct contact as required in IEC 61936-1:2021, 8.2.

The possibility of remote switching (e.g., via SCADA or a pendant control) shall be given and can be selected whenever required by local health and safety or operator rules.

[3] The classification of high voltage can differ depending on regional definitions of voltage thresholds.

7.4 Low voltage installation

The voltage thresholds which classify an installation as low voltage (LV) can differ depending on regional definitions. The standards applicable to electrical installations shall be determined based upon the voltage of the installations and the voltage thresholds defined in the scope of those standards.

- Electrical installations not exceeding 1 kV AC, or 1,5 kV DC shall be designed according to IEC 60204-1, IEC 60364-4-41, IEC 61439-1 and IEC 61439-2 where applicable.

All cabinets shall be labelled to enable identification.

Cabinets containing elements that store energy shall have a self-discharge system that prevents access to charged elements.

7.5 Electrostatic discharge

The design and construction of the wind turbine shall prevent hazardous situations due to electrostatic electricity.

The main origin for static electricity in wind turbines is caused by triboelectric effect (friction) and charge induction (electrostatic induction) and weather conditions. Triboelectric effect (friction) is typically seen in relation to surfaces with low conductivity which are exposed to friction. These surfaces can build up an electrostatic charge, e.g., blades, nacelle canopy, rotating parts, helicopters when loading and unloading goods/persons on wind turbines.

It shall be possible to discharge static electricity also during installation and commissioning.

It shall be possible to establish temporary connections for static discharge during service and maintenance, where the permanent connections have been disabled.

Mitigations implemented as lightning protection can also reduce risks from electrostatic electricity.

Helihoist platforms floors shall be designed with sufficient conductivity and connected to the wind turbine earthing system, ensuring immediate equipotential between helicopter and wind turbine when the grounding cable is lowered onto the platform.

7.6 Batteries and UPS

For UPS, IEC 62040 series and IEC 60950-1 shall be followed.

For batteries, IEC 62485 series shall be followed.

7.7 Arc flash mitigation and modelling

The design of a wind turbine shall take into consideration the impact of arc flashes in every component and area of the wind turbine.

During the design phase of the wind turbine, various arc flash studies considering different scenarios shall be performed to understand the impact of the arc flash(es) and the level of personal protective equipment required to operate such equipment.

The scenarios shall consider the different fault and voltage levels and respective protection settings. This includes, but is not limited to, the highest fault level ratings for all possible HV and LV installation options within the wind turbine (HV switchgear and associated protection devices, HV/LV transformer, LV breakers and converter-generator combinations including settings).

The results of the arc flash studies shall be considered in the risk assessment and the residual risks shall be stated in the instructions of the wind turbine.

The design of HV and main LV breakers shall ensure that the manual operation of the electrical equipment can be performed safely.

8 Mechanical systems

8.1 General requirements

Requirements for mechanical systems in onshore and offshore wind turbines are outlined in IEC 61400-1, IEC 61400-3-1 and IEC TS 61400-3-2, which shall be used.

Means for isolation of energy sources shall be provided.

8.2 Foundations and substructures

8.2.1 General

Foundations and substructures with basements (room(s) below entrance), shall incorporate the following methods:

- For effective connection of lightning protection, refer to IEC 61400-24 for specifics on protection zone definition and testing.
- For provisions regarding cable laying and cable pulling, loads from cable installation shall be taken into account for the support structure when the support structure is used to carry these concentrated loads. In the case that excessive loads will be experienced during installation and maintenance, provisions for mitigating these loads shall be made i.e., cable pulling, electrical equipment replacement.
- In the event that electrical components are installed in a basement, water ingress should be avoided. In case water could be expected within any portion of the turbine, the expected water levels and the subjected potential hazards shall be evaluated during the risk assessment phase.
- In case gases, (e.g., at brownfield site, SF6), could be expected within the basement, the subjected potential hazards shall be evaluated as a confined space, see 9.3.6

8.2.2 Specific requirements for offshore substructures

8.2.2.1 General

Any platforms above the waterline shall be secured against accumulation of potential hazardous gases from the substructure or components placed anywhere below the entrance platform. Depending on the specific design, one or more of the following methods shall be applied in order to eliminate the risk.

- a gas tight seal below the entrance platform;
- natural ventilation of the area below the gas tight seal;
- forced ventilation of the area below the entrance platform (part of the tower ventilation);
- direct ventilation to free air of gases emitted from components placed below the entrance platform.

The area below the gas tight seal will normally be considered as a confined space.

8.2.2.2 External platforms

In addition to the static requirements from the ISO 14122 series for platforms and guardrails, impact from the environment, e.g., wave loads, shall be taken into account.

8.3 Tower

8.3.1 Tower internals

If the turbine is equipped with a lift, the following shall be implemented:

- structure for connecting and supporting lift guide mechanism(s). For ladder guided systems, the ladder shall be verified as suitable for the application;
- access platform or auxiliary means to service the lift support structure(s) without climbing on the lift.

8.3.2 Cable management

If the ladder structure is to be used for supporting cables, the support (bosses, rails, etc.) shall be sized accordingly.

8.4 Yaw system

The main hazard in the yaw system is crushing due to moving or rotating parts.

The yaw system is active when it is under power, whether in automatic or under manual control. The yaw system can be active or inactive while persons are in the wind turbine.

Moving and rotating parts shall be designed and constructed in such a way as to prevent risks of contact which could lead to injury. Where the elimination of hazards is through the use of safety distances or closure of gaps, this shall be done in accordance with ISO 13857 and ISO 13854 respectively. Where it is not possible to prevent risks by means of safety distances or gaps, access to such parts shall be prevented by means of guards or protective devices. Fixed guards shall follow ISO 14120. Interlocking movable guards shall follow ISO 14119.

Whenever it is possible, the relative position of fixed and moving parts shall not block access ways. For example, ladders extending from the nacelle which might move relative to the tower wall.

Start-stop of the yaw shall not cause excessive acceleration. The rotational speed shall not cause dynamic moves which can affect the activities or the personnel.

Following ISO 14118, it shall be possible to prevent unintended starts or movements of the yaw system when maintenance works are carried out. Where possible, local control of the yaw system shall be implemented.

To prevent the yaw system from slipping during maintenance works, the yaw system can be either braked or mechanically blocked. When using the brake, the brake shall be sized to withstand the relevant loads and following the safety function considerations in Clause 5.

8.5 Blade pitch system

The main hazard in the blade pitch system is crushing due to moving or rotating parts, during maintenance activities.

The blade pitch system is active when it is under power being in automatic or under manual control.

It shall be possible to prevent unintended starts or movements of the blade pitch system, when maintenance works are carried out in the system following ISO 14118.

It shall be possible to operate and lock the blade pitch system. Locking can be by a mechanical lock or through motor and/or hydraulic fixing. If braking or hydraulic methods are used, the system shall be designed to withstand the relevant loads and following the safety function considerations in Clause 5.

It shall be possible to operate the blade pitch system for adjustments, lubrication, cleaning, repair, exchange of component(s) etc. from a local position.

8.6 Hub and spinner

Access opening(s) into the hub and spinner shall be provided with interlocking movable guards in conjunction with a rotor system lock. Access into the hub and spinner shall be prevented while they are free to rotate. For detailed guidance on access, see Clause 9.

Means shall be in place to prevent a person from being trapped inside the rotor. Examples of design measures could include:

- the movable guards can be opened from the inside of the rotor without the use of tools,
- the movable guards cannot be closed while there is someone inside the rotor.

The material used for the spinner shall be suitable for the intended use and operational conditions. The material shall withstand loads created by personnel and tools during maintenance and installation activities.

8.7 Blade

For detailed guidance on access, see Clause 9.

When there is a risk of falling into the blade, the opening shall be guarded, or a platform shall be provided.

Blade design shall include a closed bulkhead in the blade root, to prevent dirt and debris from entering during operation.

In case there is a possible risk of an oil spill leaking into the blade, the blade platform shall be oil tight or otherwise use containment solutions providing the same effect, for example, use of an oil absorption system.

8.8 Hydraulic and pneumatic systems

Hydraulic systems shall be designed according to ISO 4413 and pneumatic systems shall be designed according to ISO 4414.

In the case where hydraulic systems are used for operational functions during maintenance (e.g., applying rotor lock, brake), or during periods of grid loss, it shall be possible to activate them by either an auxiliary power supply or by manual operation.

8.9 Drive train

All rotating parts shall be safeguarded where there is a possibility of personnel or equipment being harmed. Guards shall comply with ISO 14120.

Relevant portions of the drive train shall be designed to withstand the torque of an imbalanced rotor during installation or blade replacement, with the use of locking devices or tools such as turning gears.

8.10 Braking system

The braking system shall meet the requirements according to IEC 61400-1:2019, 8.8. Brake material shall not present a hazard when airborne as dust. Dust should be contained as much as possible.

Moving parts and hot surfaces of the brake system shall be guarded. Fixed guards shall follow ISO 14120. Interlock guards shall follow ISO 14119.

If there is a risk of residual heat after removing the guards, appropriate warning signs shall be implemented.

The effect of power loss on the safety of the braking system shall be considered during the design process. During periods of power loss, it shall be possible to brake the rotor by either an auxiliary power supply or by manual operation.

8.11 Rotor locking system

The rotor lock system shall keep the rotor in a fixed position. Refer to 8.5 and 8.6 for additional information.

The system shall:

- be calculated to hold the rotor as indicated in IEC 61400-1:2019 load case 8.1 in Table 2,
- be permanently installed,
- prevent accidental activation,
- have provisions for lockout according to ISO 14118,
- be readily apparent or marked with the operative and non-operative positions,
- be easily accessible.

Operational limit condition of rotor locking system (ex. design wind speed for maintenance in IEC 61400-1:2019 load case 8.1 in table 2) shall be clearly described in the instructions.

8.12 Nacelle

The material used for the nacelle shall be suitable for the intended use and operation conditions regarding mechanical structural loading.

Nacelle covers that can be opened, doors and hatches affected by wind or gravity shall be capable of being secured in the open position as well as in the closed position. They shall be designed to be held securely open in wind speeds up to the maximum wind speed allowable for maintenance of the turbine, including allowance for gusts in order to avoid potential crush hazards.

8.13 Internal crane

The crane or hoist shall be chosen to withstand the expected loads from maintenance activities. Cranes and hoists can be subject to site specific health and safety regulations. Any impact on these requirements shall be analyzed in the design phase.

The supporting structure in the turbine for such crane or hoist shall be verified as per expected loads from the crane and the expected activities.

Unexpected movement of the crane should be prevented using brakes, locks, or other limiting mechanisms.

9 Working environment

9.1 General requirements

Wind turbines are machines designed to operate automatically. After a wind turbine is commissioned, the interaction human-machine is reduced to troubleshooting, both remotely and physically in the wind turbine and maintenance activities (scheduled and unscheduled)[4]. Therefore, the wind turbine is not considered a permanent place of work. However, the provisions given in this clause are intended to achieve compliance for access, ergonomics, manual handling, etc. as described in ISO 12100. Provisions for risk management of the wind farm are not part of this document.

The general requirements for access to all working areas shall be in accordance with the ISO 15534 series using the 99th percentile (P99) and with the ISO 14122 series for working, access and egress.

Due to the nature and design of the wind turbine, specific requirements are stated to supplement and deviate from the requirements of the ISO 14122 series and the ISO 15534 series.

In addition, in cases not covered by this document and the ISO 14122 series, ISO 15534 series shall be considered.

Additional requirements for evacuation, escape or rescue are described in Clause 12.

Where structural limitations do not allow full compliance with the ISO 15534 series and the ISO 14122 series, functional requirements shall be assessed, and the associated risk minimized to an acceptable level as described in ISO 12100. Evacuation, escape and rescue shall be demonstrated as per Clause 12.

Control panels, operational switches, etc. shall be placed so that unintentional operation is prevented.

9.2 Access

9.2.1 General

Any means of access within a wind turbine shall consider:

- purpose for which the means of access will be used, i.e., for servicing, maintenance and inspection,
- expected mechanical loads derived from the use or temporary storage of tools, parts, or components, consumables, etc.,
- the wind turbine shall be provided with evacuation/escape and rescue routes in accordance with Clause 12,
- bolts protruding to access, or evacuation routes shall have a protection cap where possible.

Selection of the means of access shall be in accordance with ISO 14122-1. Stepladders ranging from 60° to 75° shall be avoided to prevent their incorrect use.

[4] The wind turbine is manned during erection/putting into service, service/maintenance and taking out of the service/decommissioning. The number of days manned depends on several factors like site location, size of the wind turbine, weather conditions, etc. It is estimated that a wind turbine is manned 5 % of its lifetime. It is estimated that a wind turbine manned with the maximum allowed number of persons is less than 1 % of its lifetime.

When the height that the operator shall climb is more than 30 m, a powered access system should be provided[5]. Service lift is preferred before climb assistance.

Walkways, stairs and ladders can have a curved path following the structure or components in a uniform manner when this is the most appropriate for having a predictable and safe access (e.g., stairs following tower shape). The principles of the ISO 14122 series regarding stepping distances shall be followed.

9.2.2 Doorways

9.2.2.1 General

Dimensions for whole body access shall be calculated with the appropriate anthropometric data as per the ISO 15534 series, considering body movements, PPE, clothing, equipment, machine operating conditions, electrical installations, escape and rescue, frequency/duration of use.

All doors shall open in the direction of the evacuation/escape.

Doors and gates shall be able to open from inside with no key or tool even if locked, to prevent persons from being locked inside.[6]

9.2.2.2 Main access to the tower

Main access door in the tower shall have a minimum height of 2 100 mm and width of 800 mm. The corners on the opening may be rounded. But the opening shall have a flat section at the bottom of minimum 500 mm width. See Figure 1.

Dimensions in millimetres

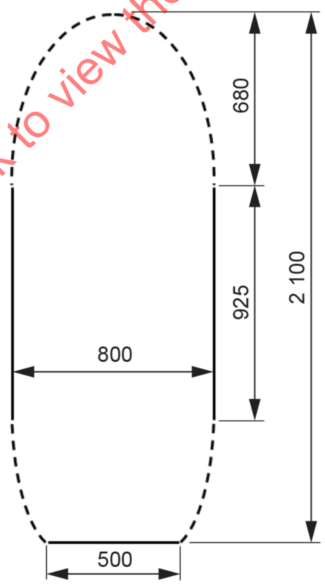


Figure 1 – Sketch of minimum door opening size

5 Refer to EN 15856:2020, Cranes – Access, 5.1.

6 Applicability needs to be verified for doors/gates in combination with interlocking devices and aimed at avoiding entrapment. (e.g., see IEC 61936-1:2021, 7.5.5).

The door shall have a locking device both in open and closed positions to prevent unintended hazardous movements caused by strong winds[7] which could cause crushed extremities.

Opening or closing the main access door shall not exceed a maximum force of 80 N[8] for a door not under pressure or not affected by the wind.

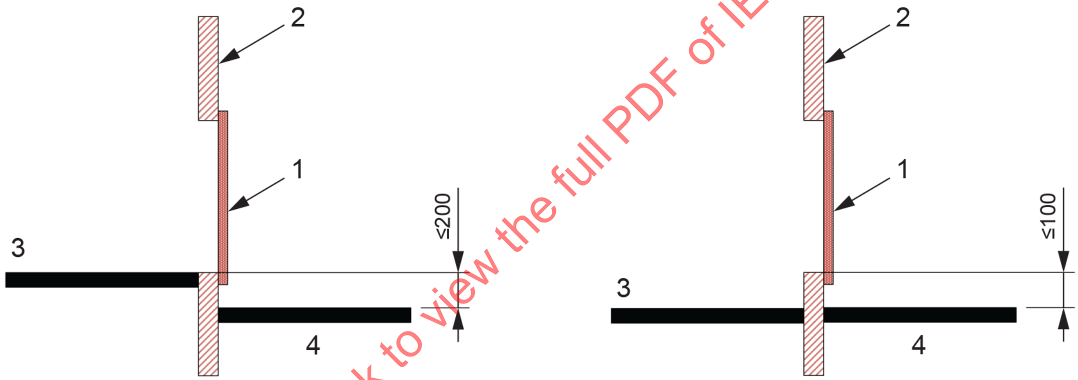
The door shall be constructed such that trespassing is minimized and intruders cannot gain access without breaking the door.

The door shall be able to open from inside with no key or tool even if it is locked, to prevent persons from being locked inside.

The passage through the door shall be designed so that it is levelled. If not possible, the trip hazard shall be reduced (see Figure 2) by designing either

- height difference between internal and external platform, which shall not exceed 200 mm, or
- the internal platform and the external platform at the same level. Height difference between platforms and door frame shall not exceed 100 mm.

Dimensions in millimetres



Key

1 tower door

2 tower wall

3 internal platform

4 external platform

Figure 2 – Transition between internal and external platform

The length of the external platform at entrance door shall be no less than the width of the door plus 1 m, see Figure 3:

7 Consider the maximum wind speed and wind gusts allowed when personnel are inside the turbine.

8 EN 1125:2008, 4.2.2.1.

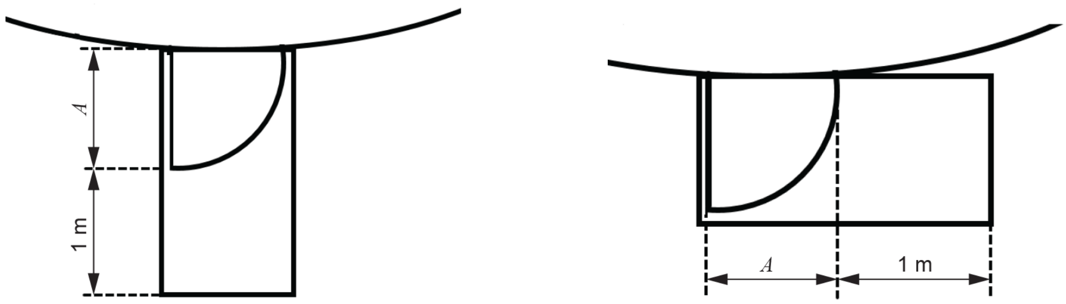


Figure 3 – External platform at entrance door

9.2.2.3 Doors and gates

Fall protection barriers shall be self-closing, unless otherwise specified by the applicable standards for a specific system, e.g., if a service lift gallery is provided with an interlocking mechanism that prevents the gate from opening when the service lift is not in position.

The necessary force to operate a door or gate (not under pressure or with sealing to make it air/watertight, etc.) shall not exceed 50 N.

9.2.2.4 Openings

Access openings shall follow the ISO 15534 series. They shall be designed to avoid crawling.

Where limitations exist, the size of the manhole can be modified. Specifically, the minimum size of the minor axis is A_{minor} = 576 mm and the minimum size of the major axis is A_{major} = 776 mm as per Figure 4.

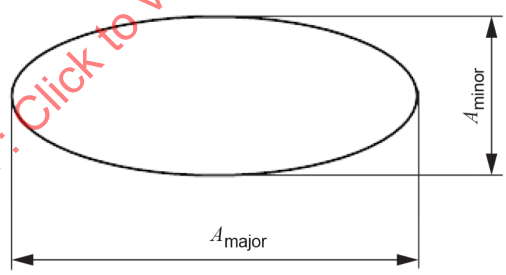


Figure 4 – Modified size of manholes

Dimensions of the openings in vertical ladders can be reduced as per ISO 14122-4.

9.2.2.5 Hatches

Hatches that can be affected by the wind shall have a locking device, both in open and closed positions, to prevent unintended hazardous movements caused by strong winds, gust, etc. which could cause crushed extremities.

When the hatch is used for access and needs to be kept open, additional control measures shall be implemented in design to prevent persons from falling through the open hatch.

Hatches used in emergency scenarios shall follow the requirements stated in Clause 12.

Opening through floors and platforms shall have self-closing hatches. Self-closing mechanism shall not cause additional risks such crushing by e.g., having a damper or a counterweight. If it is deemed necessary to keep the hatch open for a longer period of time (e.g., for a rescue operation), a device to hold the hatch open is acceptable as long as the locking function is designed so that the hatch will not unintentionally stay in open position.

Opening through floors and platforms without self-closing hatches shall be protected with a guard rail or other more appropriate means of fall protection.

The force necessary to open a hatch shall not exceed 50 N.

Hatches placed on a horizontal surface shall not open downwards and shall be supported in closed position by the structure.

Hatches placed in a horizontal surface shall be able to withstand the same loads as the floor as described in ISO 14122-2 and 9.2.

9.2.3 Stairs and stepladders

Non fixed access means such as portable platforms, ladders, stepladders, etc. should be avoided.

Stairs to external platform at the main access door to the tower shall have a minimum width of 800 mm.

9.2.4 Fixed ladders

Fixed ladders shall be designed in accordance with ISO 14122-4. Guide type fall arrester on rigid anchored is preferred on ladders longer than 6 m.

Short ladders (<6 m) should have positive inclination, preferably 75°.

Tolerances for spacing of rungs, assembly of ladder elements in tower sections and assembly of ladder elements between tower sections shall be as indicated in Table 1:

Table 1 – Tolerance for spacing of rungs

Location	Tolerance	Additional requirement
Individual ladder elements	Rungs equally spaced max ± 2 mm	
Assembly of ladder elements	Max ± 4 mm distance between rungs of the adjacent ladder elements	
Assembly of ladder elements between tower sections	Max ± 25 mm distance between rungs of the adjacent ladder elements	Warnings shall be placed clearly and visibly in the field of view of the climber and around 1 m below assembly and around 2 m above assembly if tolerances cannot be kept down to max ± 4 mm

When the ladders are designed for other purposes than access (e.g., cable holder, double hook climbing, rescue operations, work-positioning, lifting operation or evacuation from service lift), these shall be designed according to additional loads and purpose.

In case a guided fall arrest system is used, then the 3-dimensional additional loading from it shall be included in the design loads.

Arrangement for transferring between a platform and ladder with a guide type fall arrester shall be designed so that personnel can connect or disconnect from the guided fall arrest system safely e.g.:

- ladder and fall arrester shall extend at least 1,1 m above the standing surface (platform/hatch),
- there shall be a continuous line leading to a fully guarded platform (ISO 14122-4:2016, 5.5.2.2),
- connect or disconnect from the guided fall arrest system in a place where personal fall protection is not required.

Shape/size/cross-section for handholds, handles or grips shall be designed according to the requirement for handrails in ISO 14122-3. They shall be able to withstand a minimum pulling force of 1,5 kN in the relevant directions, with a safety factor of 2 without permanent deformation. If used for other purposes, they shall be designed according to the additional loads and purpose. The strength and stiffness of handholds, handles and grips can be verified by means of calculations or tests. An example of location of handles or grips can be seen in Figure 5.

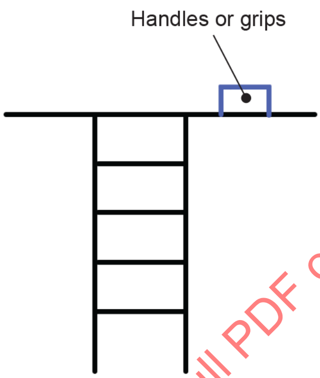


Figure 5 – Example of handle

The side-step distance measured from the centerline of the ladder to the edge of the platform shall be maximum 510 mm, see Figure 6:

Dimensions in millimetres

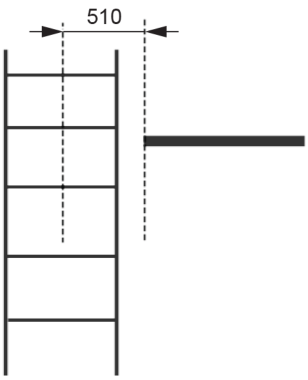


Figure 6 – Side-step distance

In case the permanent obstacles as defined in ISO 14122-4 behind the climbing area are wider than 200 mm, and the passage dimensions are less than 750 mm, a deflection plate shall be installed. The flanges in the tower piece connections are considered permanent obstacles. The lower end of the deflection plate shall be at least 800 mm away from the ladder, see Figure 7:

Dimensions in millimetres

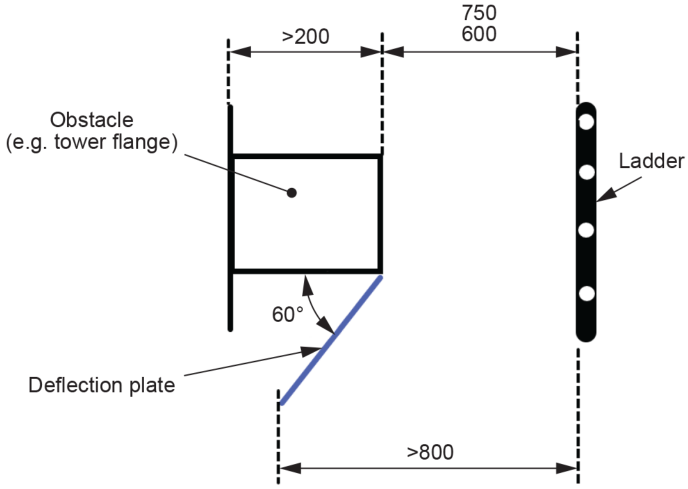


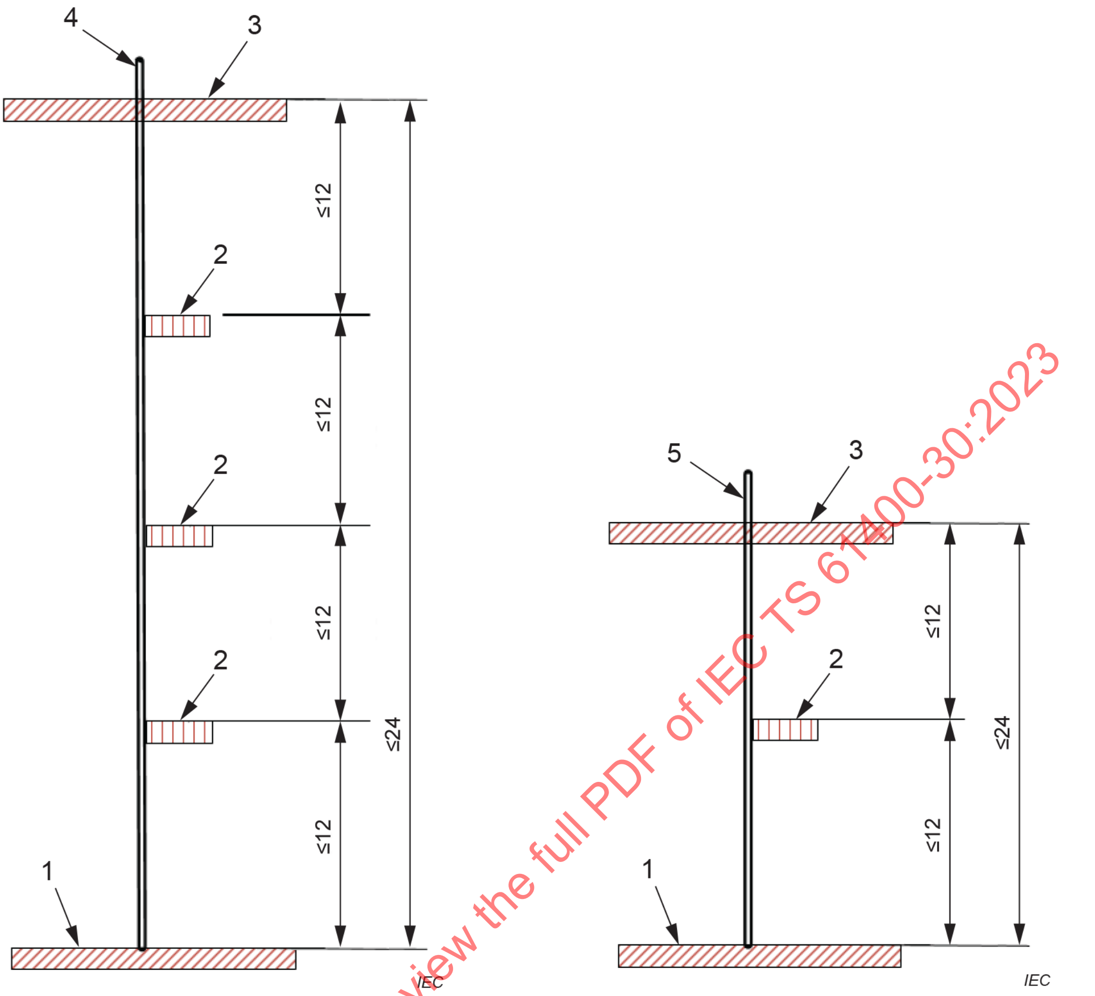
Figure 7 – Obstacles in ladder climbing area

Requirements for rest platform and moveable rest landings are listed in Table 2.

Table 2 – Requirements for rest platforms and moveable rest landings

Ladder fall arrest system	Requirements for rest platforms and moveable rest landings	Illustration
Rigid anchor line intended for use with a guided type of fall arrest. The anchor line is attached to the fixed ladder or other structure at a number of locations at intervals along its length. The system shall allow the user to lean back/away/into the system and hereby support the weight of the body, while standing on the rungs/moveable rest landing.	Rest platforms shall be provided at maximum intervals of 48 m. Intermediate movable rest landing as per ISO 14122-4 shall be provided at maximum intervals of 12 m.	Figure 8a
Other types of ladder type fall arrest systems	Rest platforms and movable rest landings shall be provided as per ISO 14122-4.	Figure 8b

Dimensions in millimetres



a) Resting platforms, rigid anchor line

b) Resting platforms, other fall arrester systems

Key

1 departure area, rest platform

2 moveable rest landing

3 arrival area, rest platform

4 fixed ladders with rigid anchor line intended for use with a guided type of fall arrest (schematic drawing)

5 fixed ladders with other types of fall arrest systems (schematic drawing)

Figure 8 – Resting platforms

9.2.5 Provisions for personal fall protection

9.2.5.1 Anchor points

Anchor points for personal fall protection equipment shall be present on those locations where the danger of falling exists and no guardrail can be constructed (e.g., a step-up, a hatch opening, a standing place, a platform, a ladder-end) or where they are required for escape or rescue.

Anchor points for personal fall protection equipment shall be as follows:

- They shall be placed as high as possible to minimize the free fall distance, preferably and if possible, placed at 1,9 m to 2,0 m above the standing surface.
- Anchor points below waist height are only acceptable for fall restrain (if the person cannot fall to a level lower than where his/her feet are standing).

- The pendulum effect and the clearance distance below anchor point shall be considered together with the prescribed fall protection.
- Consecutive anchor points shall be placed so that the persons can move from one anchor point to the next and be attached to both anchor points simultaneously.
- They shall offer an opening with a minimum size of 30 mm diameter and have a cross section diameter/width with a maximum of 20 mm, see Figure 9.
- They shall not have sharp edges inside or outside.
- They shall be coloured uniformly yellow (e.g., RAL 1023) to contrast with the background. If the anchor point is placed on a yellow surface, the area around the anchor point shall be colored so the anchor point is visible.

Dimensions in millimetres

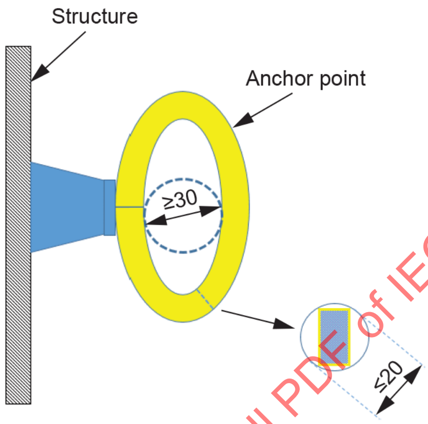


Figure 9 – Anchor point dimensions

- They shall be verified for the number of users allowed (n).
- Only one personal fall arrest equipment/system per attachment opening is allowed.
- The number of users for fall restrain (including the use of rescue/descent devices) can be higher than the number of users for fall arrester, see Table 3. Only one rescue/descent device per attachment opening is allowed.
- They shall be verified as per ISO 14567 with the following deviations:
  – Rigid test mass of 150 kg for dynamic test;
  – The design load shall be the maximum arresting force[9] with the safety factor of 2;
  – Permanent deformation is allowed if the anchor points are set to be replaced;
  – Permanent deformation is not allowed if the anchor point is not meant to be replaced (no exchange after arresting a fall).

[9] The force which the anchor point and structure will be exposed to will depend on the fall arrest system used. It is a requirement that the user shall be equipped with means for limiting the dynamic forces exerted on the user during the arrest of a fall. EN 795 restricts the maximum force to 6 kN and in OSHA 1926.502 the maximum arresting force is 8 kN.

Table 3 – Fall protection loads

Fall protection type	Loads
Fall arrest	1 user: F = 2 × arresting force and ≥ 12 kN[10] 2 or more users(n): F = 2 × 2 × arresting force + (n – 2) × 2 × 1,5 kN
Work positioning Limited free fall/travel restrain	F = 2 × n × 1,5 kN and ≥ 12 kN No permanent deformation at F = 2 × n × 1,5 kN
Rescue and escape emergency descent	F = 3 × n × 1,5 kN and ≥ 12 kN Shall be able to withstand multiple successive descents
Rope access, (2 separate points, one for primary and one for secondary rope)	F = 2 × n × 1,5 kN and ≥ 12 kN No permanent deformation at F = 2 × n × 1,5 kN
Key F = force [kN] n = number of users	

- Anchor points for emergency evacuation/escape and supporting structure shall be heat resistant during the required time as per Clause 12 (RSET).
- They shall be marked with:
  – the model or type identification,
  – the batch or serial number,
  – the pictogram of the number of persons allowed for fall arrest, e.g., ISO 7001 PI BP 018 can be used.
- They shall include in the instructions for use:
  – standards used for the design of the anchor point;
  – number of persons for fall arrester and for fall restrain (rescue and/or descent devices, work positioning rope, etc.);
  – statement of the limitations for the anchor points;
  – instructions that immediately before use, the user shall make a visual inspection of the anchor point);
  – instructions of what to do with the anchor point after a fall has been arrested (e.g., inspection and/or replacement).

9.2.5.2 Structure used for fall protection

Structures expected to be used for anchorage shall comply with the following points:

- They shall not allow deformation in the main load carrying structure of the wind turbine, because it cannot be replaced.
- The intermediate components/brackets in between the anchor point and the main load carrying structure, which is part of the "fall arrester system", shall be replaced if deformed.
- When deformation is allowed, it shall not prevent the retrieval of a person by a rescuer.
- The design load shall be calculated as indicated in Table 3.

[10] In Australia, according to AS/NZS 1891-4: 2009, the design load is minimum 15 kN.

Structures for anchor points can be verified by analytics methods in ductile materials. Non-ductile materials shall be verified by testing and calculation. Calculated performance shall not deviate significantly from the test result.

Designated structures intended for the use of movable anchor points shall be painted yellow (e.g., RAL 1023) where the anchor point is to be installed.

9.2.6 Access platforms

Platforms, walkways and standing areas shall be designed in accordance with the ISO 14122 series.

Slip resistance shall be determined by a well-established standard or guidance, such as EN 16165:2021, Annex B Shod ramp test[11].

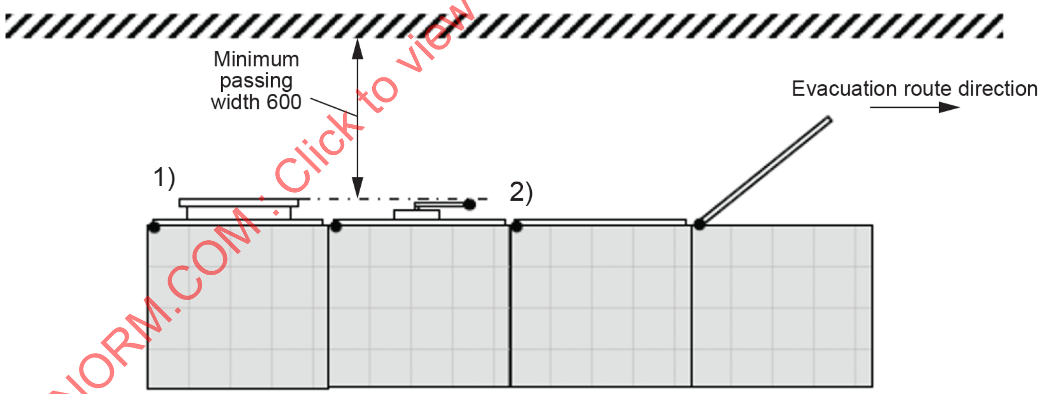
For walkways not having a clearly defined rectangular passage as per ISO 14122, other standards can be applied to define the minimum height and width of the passage. This can be applicable to restricted spaces, passages, or walkways with no clear or other geometric shapes (ellipse, trapeze, etc.). Guidance is given in Annex B.

9.2.7 Space in front of electrical panels[12]

Minimum width between enclosures and the wall, or other obstructions shall be 700 mm.

Minimum width between switch handles and wall, or other obstructions shall be 600 mm, see Figure 10.

.



1) Circuit-breaker in the isolated position

2) Handles (e.g., for controls or equipment)

Source: Figure 729 A.1 of IEC 60364-7-729:2007

Figure 10 – Space in front of electrical panels

To permit easy evacuation, the doors of any electrical equipment shall close in the direction of the evacuation route.

11 If EN 16165:2021, Annex B Shod ramp test is used, the critical angle should be: Inside > 6°; Outside > 19°.

12 Enclosure which contains a combination of one or more low voltage switching devices together with associated control, measuring signalling, protective, regulating equipment. This does not include junction boxes, box-type assemblies or multi-box-type assemblies.

If the evacuation is needed in both directions, the door shall be able to open close to 180°. Alternatively, the passing width between the edge of the open door and the opposite side of the access way shall be minimum 500 mm (see Figure 11).

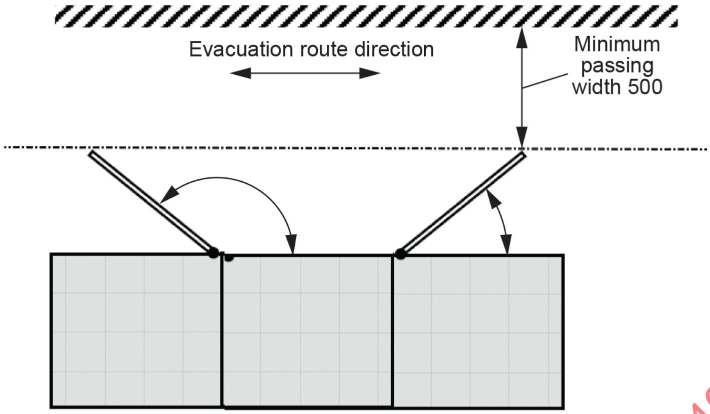
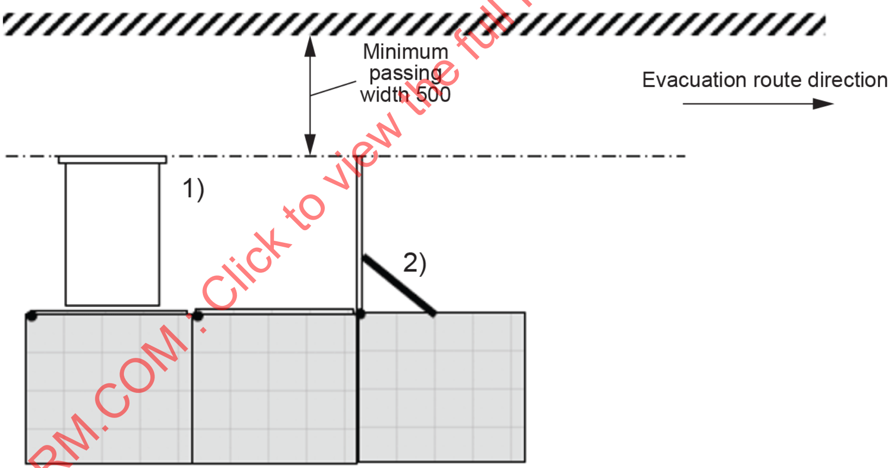


Figure 11 – Evacuation in both directions and passing width

For doors which can be fixed in open position or circuit breakers or other components which can be withdrawn from the cabinet for maintenance, a minimum passing width of 500 mm shall be available (see Figure 12). Alternatively, it shall be possible to evacuate in both directions (see Figure 13).

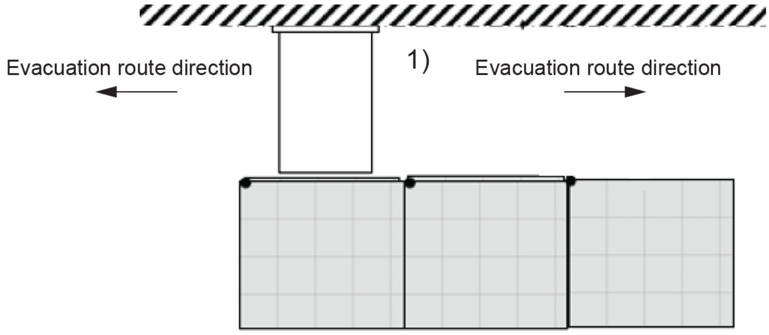


1) Completely extracted circuit-breaker

2) Door fixed in open position

Source: Figure 729 A.3 of IEC 60364-7-729:2007, modified, explanation of minimum width not required.

Figure 12 – Minimum passing width, evacuation in one direction



1) Completely extracted circuit-breaker

Figure 13 – Evacuation in both directions

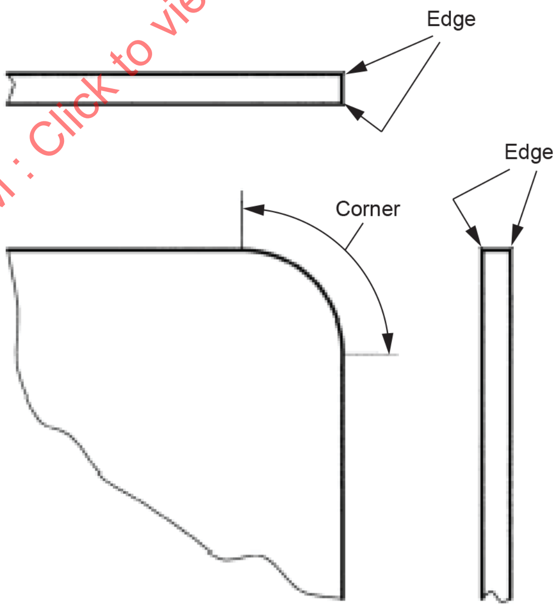
9.2.8 Bluntness of edges

Edges and corners (see Figure 14) of metallic and non-metallic materials on accessible parts/areas of the wind turbine shall be void of sharp edges which can cause contusions or penetration of the human skin.

Edges of parts shall be rounded or chamfered to a minimum dimension of 0,3 mm as shown in Figure 15 or be fitted with a protective strip. For edge thickness of 1 mm or less, a protective strip shall be fitted.

External corners such as on service doors and pointed objects shall have a minimum radius of 4 mm, see Figure 14.

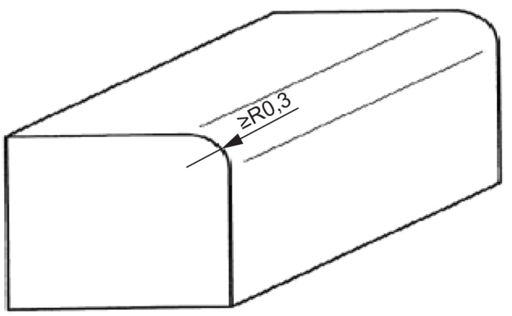
Grab-handles and edges/corners of handholds shall have a minimum radius of 5 mm or chamfered minimum 5 × 5 mm.



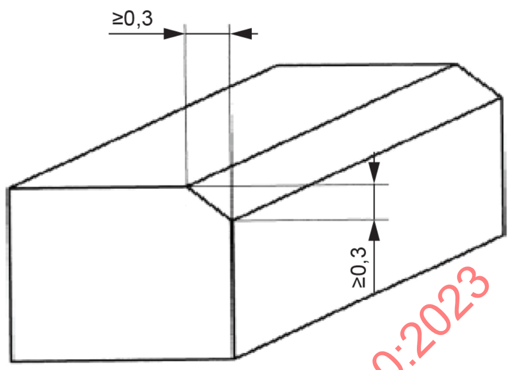
[13] ISO 12508:1994 Copyright © 2023 ISO Geneva, Switzerland. www.iso.org .

Figure 14 – Edges and corners

Dimensions in millimetres



a) **Radius**



b) **Chamfer**

Reproduced with permission from ISO 12508:1994. ISO has no responsibility for the placement and context (including other content or accuracy) in which the extracts are reproduced, nor is ISO in any way responsible for the other content or accuracy therein. [14]

Figure 15 – Edge radius and chamfer for parts

9.2.9 Climbing assistance

For the purpose of this document, climbing assistance is an appliance used to relieve persons from part of the required effort to climb up or down on vertical ladders. The design shall be based on attaching the user´s harness to an endless rope powered by a drive unit or to a powered device that runs along the ladder in such way that it pulls the user in the upwards direction. The use of a climbing assistance shall always be combined with the use of a fall arrest.

The pulling function of the climbing assistance shall always require a positive climbing or descending action from the user to activate.

Climbing assistance may be used as an alternative to the service lift when providing a service lift is not possible (e.g., tower design and wind turbine component arrangements does not offer enough space to meet the requirements).

At the time of drafting this document, there is no specific standard regarding climbing assistance, however the minimum requirements for the design or the selection of this type of systems are outlined in Annex C.

9.2.10 Service lift

A service lift shall be available when climbing height in the tower is more than 60 m.

The service lift shall be designed according to generally accepted industry standards.

National regulations and design references for the design of the wind turbine service lift and its interfaces can exist.

[14] ISO 12508:1994 Copyright © 2023 ISO Geneva, Switzerland. www.iso.org .

9.2.11 Helihoist and aviation aids

9.2.11.1 Helihoist

The winching area platform (clear area) should be square or rectangular and capable of containing a circle having a minimum diameter of 4 m. It shall be painted yellow.

If there is a space in the surroundings of the winching area for storage or other functional needs, this area shall not be painted yellow.

The helihoist shall be designed to avoid accumulations of liquids.

In addition to the winching area platform, provisions shall be made for a safety zone to accommodate helicopter hoist operation passengers at a safe distance away from the winching area. The minimum safe distance shall be no less than 1,5 m from the inboard edge of the winching (clear) area in all direction and levels.

The surface of the platform, including the safety zone and associated access route, should display suitable friction characteristics to ensure the safe movement of helicopter hoist operation passengers in all conditions. The minimum friction coefficient, which should be verified prior to installation, slip resistance shall be as per 9.2.6.

The winching area platform, including the safety zone and associated access route, shall be completely enclosed by a fence as per CAP 437, with the exception of the fence height, which shall be as a minimum 1,5 m.

The design of the safety rails shall ensure that a free flow of air through the structure is not prevented. It shall also prevent the hoist hook to get entangled in the railing or in any other part of the platform structure (e.g., by putting a mesh).

During hoist operations, the minimum clearance between the helicopter rotor blades (at hover height) and the wind turbine rotor blades should be 5 m, see Figure 16.

An example of a helihoist layout can be seen in Figure 17.

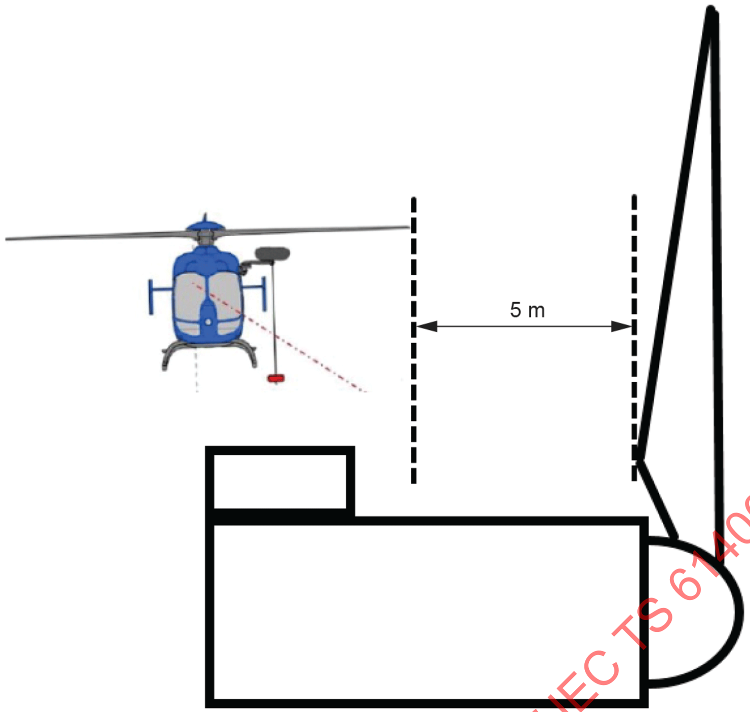
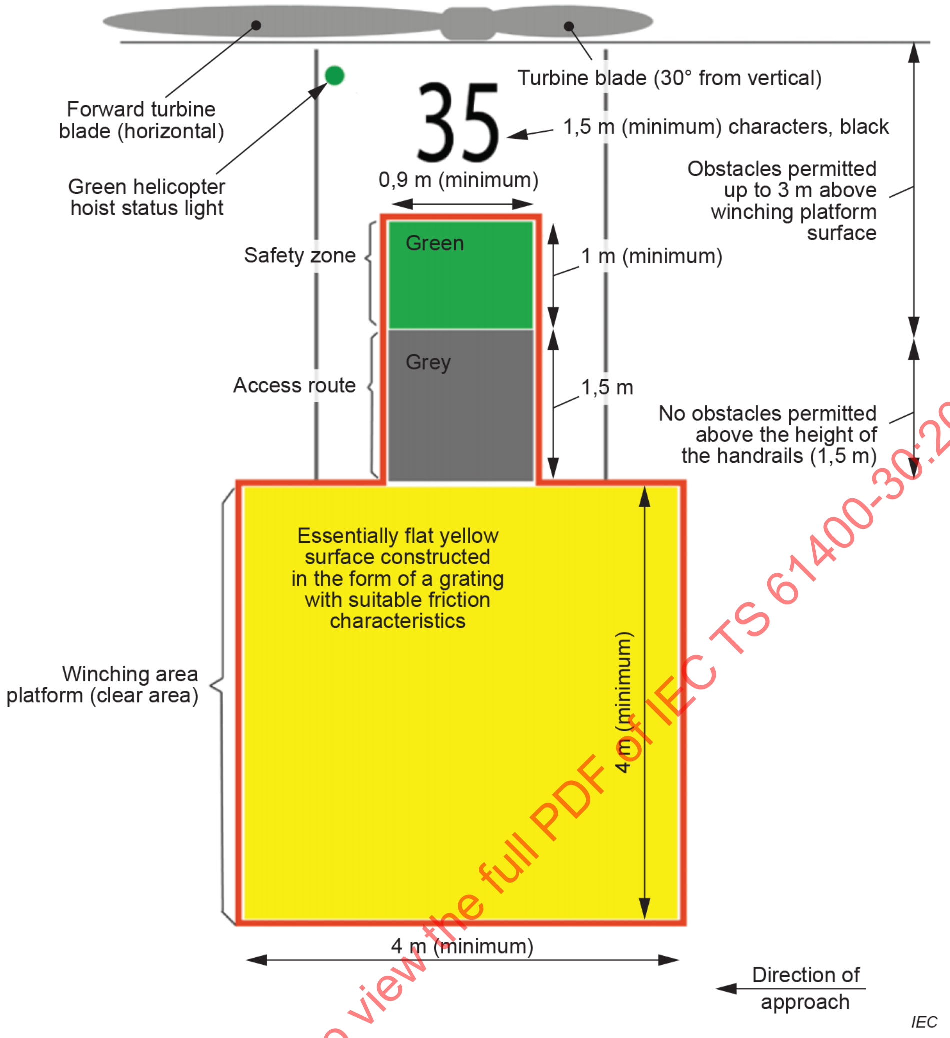


Figure 16 – Minimum helicopter distance to blade



NOTE Blade orientation can vary to suit operational requirements.

Source: CAP 437, with the permission of CAA (Civil Aviation Authority), modified in the fence height due to requirements in different countries. [15]

Figure 17 – Helihoist layout example

9.2.11.2 Aviation aids

Aviation aids shall be understood as those features helping a helicopter pilot to perform helihoist operations. Obstacle aviation lights and markings are excluded from this document.

All lights shall have the function to be turned on/off individually on request via SCADA.

There shall be an emergency uninterruptable power system for 6 h of operation, compliant with ICAO Annex 14, 9th Edition, July 2022.

The wind turbine structure should be clearly identifiable from the air using a simple designator, in 1,5 m (minimum) characters in a contrasting colour, preferably black. The tower and the blades shall have a white or grey uniform colour on minimum 80 % of the outer surface.

[15] Reproduced from CAP 437, with the permission of CAA (Civil Aviation Authority), modified in the fence height due to requirements in different countries.

9.2.11.3 Static electricity

Helihoist platform floors shall be designed with sufficient conductivity and be connected to the wind turbine earthing system, ensuring immediate equipotential between helicopter and turbine when grounding cable is lowered onto the platform and be able to take the charging current from the helicopter so equipotential between helicopter and turbine can hold.

9.2.12 Offshore vessel access

9.2.12.1 General

If transfers during the hours of darkness could be undertaken at any point in the life of the structure, suitable lighting should be provided on crew transfer vessels and/or the structure.

9.2.12.2 External ladders for boat landing

In addition to the normal fixed wave loads and offshore conditions, requirements from IEC 61400-3-1 shall be considered.

For offshore access design, which includes a ladder on a boat landing, the following additional requirements shall apply:

- The boat landing shall ensure a safe zone for the person transferring without risks of crushing between the vessel and boat landing. The safe zone shall be minimum 500 mm, measuring the shortest distance between the vessel and the ladder.
- The boat landing shall ensure a maximum stepping distance of 650 mm measured from a suitable and safe non-skid surface on the vessel to the ladder on the substructure.
- Rungs shall be orientated with edges pointing up-down.
- The rungs shall have a distance of at least 200 mm from the substructure wall and have space for climbing according to the ISO 15534 series.
- The distance between the ladder stiles shall be 500 mm ± 50 mm.
- Rungs and stiles shall be designed to be used as anchor points and withstand loads as described in 9.2.5.
- The ladder shall be equipped with a fall protection system designed to be used in a maritime environment.
- A retractable fall arrester should be preferred to guide the fall arrest system due to sea growth, icing, etc.
- The fall protection system shall be safely accessible from the access level (the vessel), from the ladder and from the departure area.
- Safety cages should not be used for fall protection of the external ladder.
- Rest platforms are not allowed in the boat landing area even if it exceeds 12 m. This area is a risk zone due to moving vessels, sea growth, slippery surfaces and splash zones, persons should not be motivated to stay in this area longer than required.
- If the distance between the lower possible access points to the top of the boat landing exceeds 12 m, a rest platform shall be provided immediately above the boat landing.
- Moveable rest platforms shall not be used on the external ladders.

Ensure that the top and bottom of the bumper bars extend beyond the range of the vessel bow heights that are expected, taking account of tidal range, effect of waves and foreseeable vessel types. Furthermore, the top and bottom of the bumper bars can be angled inwards towards the substructure to minimise the risk of vessel getting stuck on top or underneath the bumper bars.

Any protrusions from the boat landing structure, such as intermediate platforms, shall be of sufficient height to ensure that they do not endanger personnel on the vessel bow when the vessel is in the highest foreseeable position on the bumper bars.

Ladder and bumper bar design should minimise protrusions that could cause injury to a climber falling from the ladder (consider that climbing with energy-absorption lanyards and scaffold hooks should be necessary if the self-retractable line is not in operation, thereby potentially increasing the fall distance). For example, the shape and position of the tops of the boat landing bumper bars should minimise the risk of these causing injury to a falling climber.

Given the need for occasional use of scaffold hooks on the ladder, the surface coating specification should seek to minimize the potential for chipping as a consequence of scaffold hook use. However, scaffold hooks should only be used if the self-retractable line is temporary out of service and not as a routing approach.

The potential for ladder/boat landing replacement/repair over the lifetime of the structure should also be considered, such as the provision of flanges or plates to enable future bolted connections.

9.3 Working conditions

9.3.1 Noise exposure

Wind turbines shall be designed and constructed in such a way that risks resulting from the emission of airborne noise inside the turbine are reduced to the lower level when personnel are present, taking into account technical progress and the availability of means of reducing noise, in particular at source.

The level of noise emission can be assessed with reference to comparative emission data for similar machinery. A method of comparing the noise emission data of machinery is given in ISO/TR 11688-1.

When designing machinery, the information and technical measures to control noise at the source given in ISO/TR 11688-1 shall be considered. Information given in ISO/TR 11688-2 can be considered.

Areas where persons can be exposed to noise levels exceeding 70 dB(A) shall be identified, marked and informed as indicated in Clause 13.

Noise levels shall be measured in the worst noise condition that can occur while there are personnel present, excluding noise from parts that do not belong to the turbine design e.g., hand tools. Emission sound pressure levels should be measured in accordance with ISO 11201.

9.3.2 Vibration

Wind turbines shall be designed and constructed in such a way that risks resulting from vibrations produced by the wind turbine and its components are reduced to the lowest level, taking into account the technical progress and the availability of means of reducing vibrations, in particular at source. The level of vibration emission can be assessed with reference to comparative data for similar machinery.

Areas where persons can be exposed to whole-body vibrations exceeding 0,5 m/s^2 shall be identified and informed as indicated in Clause 13.

Vibration levels should be measured in accordance with ISO 2631-1.

When designing machinery, the information and technical measures to control vibration at the source shall be considered. [16]

[16] Guidance can be found for example in EN 1299.

The vibration shall be measured using recognized standards or guidelines for the machinery concerned.

The operating conditions during measurement and the codes used shall be described.

9.3.3 Radiation

Electromagnetic fields shall be assessed.

Areas where a person can be exposed to electromagnetic radiations shall be identified, marked and informed as indicated in Clause 13.

Electromagnetic fields shall be assessed and mitigated in accordance with the EN 12198 series or another recognized standard.

9.3.4 Thermal

Steps shall be taken to eliminate any risk of injury arising from contact with, or in proximity to, machinery parts or material at high or very low temperatures.

If surfaces that persons can get into contact with reach temperatures above 48 °C, an assessment according to ISO 13732-1 shall be made and mitigations shall be implemented when required.

If surfaces that persons can get into contact with reach temperatures below 5 °C, an assessment according to ISO 13732-3 shall be made and mitigations shall be implemented when required.

9.3.5 Air quality

The design of the wind turbine and its components shall be such that it does not release harmful particles, dust of fumes. Preventive measures such as ventilation shall be considered.

Places where there is a risk of accidental release of hazardous materials that can affect the air quality shall be identified and informed through instructions as indicated in Clause 13.

9.3.6 Restricted and confined spaces

Restricted and confined spaces can be expected in blades, hub, generators, shafts, foundations and basements[17].

In these places, it shall be assessed and demonstrated that evacuation, escape and rescue is possible as per Clause 12.

Service tasks in these areas should be avoided, especially when heavy tools are required. If not possible to avoid, ergonomic aspects shall be evaluated.

Residual risks that cannot be reduced to an acceptable level through the design shall be identified and informed in the instructions.

---

[17] Confined spaces are subject to health and safety regulations, which can include organizational and administrative control measures such as training, entry plan, permit to work, etc.

9.4 Ergonomic

9.4.1 General

Ergonomic requirements shall be considered when designing a wind turbine, including:

- human body dimensions for access (see 9.1),
- physical strength and human power,
- postures,
- body movements,
- human machine interface.

The design of components that are to be manually handled and having a mass greater than 15 kg should be equipped with an interface for handling or lifting equipment. Lifting instructions shall be described as per Clause 13.

ISO 11228 series and EN 1005 series can be used for guidance when performing manual handling assessments.

For assessment of postures, the midrange of ISO 7250 series should be used. For assessment of physical strength and human power, ISO 11228 series should be used.

9.4.2 Human machine interfaces

Machine human interfaces include but are not limited to control panels, emergency stops, input and output boards, etc.

The human machine interfaces shall comply with the ISO 9355 series.

10 Lighting systems

10.1 General

10.1.1 Lighting for safety in wind turbines

Wind turbines shall have service lighting systems for safe access and work and emergency lighting systems for safe evacuation in case of failure of the energy supply of the service lighting systems.

Aviation obstruction lights and lighting means during installation are excluded from the scope of this clause.

All illuminance levels in this clause are considered as maintained illuminance. Maintenance factors shall be used and determined according to CIE 97-2005. Information on the determination of the maintenance factor is provided in Annex D.

10.1.2 Internal lighting

In any accessible area to service personnel in the wind turbine, permanent installed lighting shall be provided.

Light switches shall be installed next to entrance areas and shall be easy to locate.

Sockets for portable work light shall be provided to enable portable lighting that can improve the lighting conditions compared with the minimum values defined in Table 4.

Sockets for portable work light can be a substitute for permanent installed light if:

- permanent installed light introduces additional risks,
- permanent installed general lighting cannot provide the minimum illumination level (see Table 4) and portable luminaries provide better light conditions, e.g., inside panels, restricted spaces, behind cover plates (inside guards, below floor plates, etc.),
- the areas where the expected service interval is 3 years or more.

Headlights shall not be a substitute for permanently installed service light.

If the area is part of an evacuation route, sufficient emergency lighting shall be available.

10.1.3 External lighting

Outdoor lighting shall be provided on the external platforms and helihoist.

For offshore wind turbines, external lighting systems shall be remotely accessible for on/off operation via SCADA or any other means. For onshore wind turbines, it shall be considered as optional.

10.2 Design requirements for lighting systems

- All parts of lighting systems shall be exclusively used for that purpose (illumination) with the exception of safety related systems. The lighting system shall not be compromised by any other parts of systems of the wind turbine.
- It shall be possible to power the service lights when the switch gear and the main transformer are disconnected or there is no grid. External auxiliary power source can be utilized for this purpose.
- The electrical circuits supplying lighting systems shall include their own overcurrent protection and shall not supply other systems.
- Lighting systems should be designed considering glare, stroboscopic influences and other poor lighting conditions. These effects should be minimized so as not to compromise the safety of operators.
- All components of the lighting system shall be protected against damage and risk of unintentional disconnection.
- Lights should be placed and designed such that they do not cast shadows causing nuisance.

10.3 Design requirements for emergency lighting systems

In addition to 10.2, emergency lighting systems shall:

- work automatically in emergency mode less than 1 s after energy supply to the main lighting system stops when the service light switch is in on state, providing 100 % emergency luminosity levels 60 s after;
- supply emergency lighting for a period of at least 30 min or the time required to evacuate/escape to a place of temporary safety inside or outside the turbine quantified according to Clause 12 plus a safety margin of 5 min, whichever is greater;
- provide a warning when the system cannot comply with the demanded emergency lighting functionality;
- warn the operator when the system is in emergency mode if the differences between illuminance (lux) in emergency mode and normal mode are less than 50 %. This warning shall allow the operator to realize the main lighting supply stopped while working;
- be designed in such a way that the functionality of emergency lighting can be tested without disconnecting the mains power supply;
- be designed in such a way that any failure in a single component of the system does not compromise the emergency functionality of any other component or part of the system.

10.4 Illumination levels

All accessible areas to service personnel should be classified according to the following categories:

- task area: partial area in the workplace in which the visual task is carried out;
- access and evacuation paths: areas consisting of the means of access or evacuation from workspaces, including ladders;
- ladders for tower with service lifts: ladders in towers where the main means of ascend/descend is a service lift.

Internal lighting systems shall meet at least the average illuminance (E_{av}), minimum illuminance (E_{min}), minimum color rendering index ($R_{a\ min}$) and minimum uniformity (U_0) established in Table 4. Uniformity (U_0) is defined as follows:

$$U_0 = \frac{E_{min}}{E_{av}}$$

where

U_0 is the minimum uniformity;

E_{min} is the minimum illuminance;

E_{av} is the average illuminance.

Table 4 – Illuminance levels

Required illumination level	Service			Emergency		
	E_{av} (lux)	E_{min} (lux)	$R_{a\ min}$	E_{min} (lux)	U_0 (lux)	$R_{a\ min}$
Task areas	100	50	60	-	-	-
Access and evacuation paths	50	15	60	15	0,1	40
Ladders for tower with service lift	-	15	60	15	0,1	40

If some tasks are visually demanding, additional lighting can be provided with permanent light or portable light as per 10.1.2.

10.5 Illumination level assessment

10.5.1 General

The illumination levels, as defined in Table 4, can be verified by means of simulations or in field measurements.

Luminance levels shall be measured as follows:

- Task area surfaces: perpendicular to the surface at the height where the task is going to be performed.
- Access and evacuation paths (except ladders): Perpendicular to the surface at floor level (where person is standing).
- Ladders: The illuminance (lux) of a step is the smaller value between looking up or down to it. When looking up to the step, the illuminance is the greater value between the bottom and front sides. When looking down, the illuminance is the greater value between the top and front sides. It can be expressed in the following formula. See Figure 18.

$$E_{\text{step}} = \min\left(\max\left(E_{\text{TOP}}, E_{\text{FRONT}}\right), \max\left(E_{\text{FRONT}}, E_{\text{BOTTOM}}\right)\right)$$

where

E_{step} is the calculated representative illuminance (lux) of a given step;

E_{top} is the illuminance (lux) on the top of the step;

E_{front} is the illuminance (lux) on the frontal surface of the step (climbing side);

E_{bottom} is the illuminance (lux) on the bottom surface of the step.

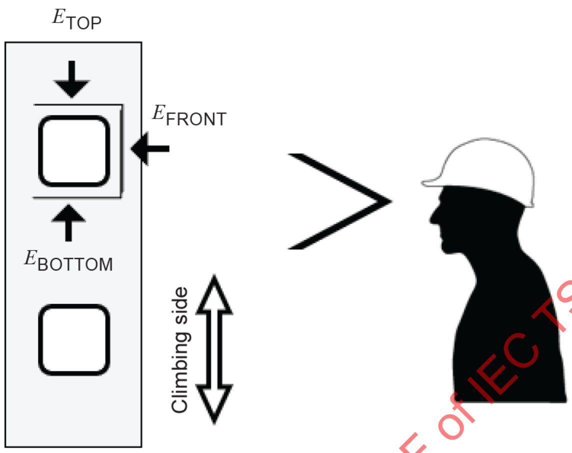


Figure 18 – Illuminance levels measurement on ladders

10.5.2 Illumination level verification

If verified in the field, the maintained illuminance levels shall be measured as follows:

- Task area surfaces:
  - Smaller than 2 m^2: minimum 4 measurements points evenly distributed;
  - Greater than 2 m^2: measurements points, evenly distributed with approximately 1 m in between.
- Access and evacuation paths: located on the center line of the path, measurements shall be taken at places where the access route changes direction or level e.g., at steps, top and bottom of stairs, turns.
- Ladders: measurement at areas where it is necessary to connect or disconnect from fall arrest system (e.g., getting on/off ladder), at stepover points when transferring from ladder to a platform and at places expected to have minimum lux level (e.g., midway between two luminaires).
- Towers with ladders in turbines without a service lift: the average values measured shall be based on the measurement for ladders as described in the point above, including additional measurements where intermediate rest landings are located.
- If there is an even distribution of luminaries throughout the tower, it is acceptable to determine the average light condition with measurements of a single tower section.

11 Fire protection

11.1 General

The fire protection system shall be designed to protect persons and property. The requirements outlined in this clause are mainly to protect persons.

11.2 Foreseeable misuses

The fire risks are different when the wind turbine is in operation or in maintenance mode. The fire risk assessment shall assess both situations for personal safety, e.g., troubleshooting.

11.3 Fire risk assessment

A fire risk assessment shall be developed, following ISO 12100 and the principles in ISO 19353:2019, Subclause 5.1 to 5.4.

The following is a non-exhaustive list of foreseeable misuses which shall be considered:

- unauthorized access,
- access to wind turbine in operation mode,
- manufacturer's maintenance schedule not followed,
- by-pass control and protection systems,
- operational procedures not followed,
- cooking/smoking.

The fire risk assessment shall be made for maintenance mode and operation mode. Effectiveness of the preventive and/or protective measures shall be assessed as well.

The residual risks from the fire risks assessment and the mitigations to put in place shall be communicated, see 11.6.

11.4 Fire hazards

Ignitions sources:

- rotating and moving parts leading to hot surfaces and sparks due to friction,
- hot works during repair activities,
- smoking and cooking,
- HV and LV components which can generate arc flashes, arc blast, overheating or short-circuits,
- resonance phenomena,
- lightning strikes,
- batteries,
- chemical material: oils, grease, dirty cleaning cloth, etc.

Combustible materials:

A wide variety of combustible materials (fire load) are used in the wind turbines such as:

- nacelle housing,
- lubricants,
- hydraulic oil,
- electrical installations, cables, batteries, etc.

Potential leakage and leakage collection shall be assessed in terms of proximity to ignition sources.

Smoke:

Smoke is a dangerous effect of a fire in a wind turbine, even for short exposure of personnel. This hazard shall be considered during the design phase to ensure that the hazards related to oxygen level and toxicity are as low as possible and that personnel have the necessary time to reach a safe place without being affected by the smoke.

11.5 Risk reduction

11.5.1 General

This subclause states a set of general requirements. The preventive and protective measures shall not be limited to the following requirements, but be used as a base or to complement a specific fire risk assessment for a wind turbine model.

11.5.2 Inherently safe design measures

Design measures and passive fire safety measures shall include but not be limited to the following:

- The wind turbine should be designed so that hot works such as cutting or welding, are not necessary during the lifecycle of the wind turbine.
- Combustible fluids shall be selected so that they have a flash point well above temperature during operation and maintenance.
- Combustible fluids shall be contained.
- Leakage shall be prevented or contained.
- The wind turbine shall allow for cleaning of spillage from oil, grease, coolant, etc. to prevent aggregation of fluids.
- Stability of the tower in case of fire shall be verified for the time required for safe escape and evacuation.
- The wind turbine shall be fitted with cooling and condition equipment to reduce overheat of components.
- The moving parts shall be equipped with an effective lubrication system.
- Electrical circuits shall comply with IEC 60204-1 and IEC 60204-11.
- The structure and/or elements used in case of evacuation (e.g., anchor points) shall withstand the fire time long enough to allow personnel to reach a place of temporary safety based on all fire scenarios in the fire risk assessment. The calculation of the time is given in Clause 12.
- Non-combustible or fire-retardant materials shall be used where required to ensure availability of the exit routes.
- Materials with low toxic emissions should be chosen where reasonably practical.

11.5.3 Safeguarding

Measures to prevent personnel from being exposed to the fire hazard:

- Appropriate arc fault protection system shall be designed. If not possible, the electrical cabinets shall be designed to withstand the potential arc flashes[18].
- Rotating parts shall be enclosed as well as the brake discs with non-combustible materials.
- Lightning protection systems shall be provided in accordance with IEC 61400-24.

[18] Arc fault protection can be achieved by explosion relief venting.

11.5.4 Monitoring and warning system

Monitoring and warning systems are designed to monitor and control specific parameters of the wind turbine during the operation mode. They shall:

- be designed to keep the wind turbine in internal environmental conditions according to IEC 61400-1:2019, 10.3;
- monitor the specific wind turbine system(s) and/or components where the fire is likely to occur and detect any malfunction which can lead into a fire;
- bring the wind turbine to a safe state. Initiate an immediate reaction to avoid the fire such as a controlled shut-down of the operation, disconnection from the power supply, etc. Critical functions to personal safety shall be available after shutdown;
- communicate the warnings to the control center;
- be active while personnel are in the wind turbine unless other preventive measures are applied to keep the same or higher level of safety.

11.5.5 Complementary protective measures

11.5.5.1 Integrated fire detection and alarm systems

The wind turbine shall be equipped with a fire detection system that shall:

- be qualified for the area to be monitored and for the expected fire scenarios;
- have an interface to the turbine control system;
- ensure immediate and controlled shutdown of the wind turbine and disconnection from the power system and send a signal of fault message to the control centre. Control functions critical to personal safety shall be available after shutdown.
- trigger an alarm to warn personnel in the wind turbine. The alarm:
  – shall be capable of warning personnel in all expected locations and conditions (e.g., visual, acoustic, etc.);
  – should indicate where the fire is via a control system if accessible from the different areas of the wind turbine or via different sounds or lights (e.g., one for the tower and one for the nacelle).

The fire protection system(s) shall be active prior to start-up of power production and remain active during the maintenance mode unless other preventive measures are applied to keep the same level of safety.

Service and test of the fire protection system(s) shall be considered in the design of the system. Service and test of the system(s) shall not expose personnel to additional risks.

11.5.5.2 Fire suppressions systems

11.5.5.2.1 General

Fire suppression systems should be installed based on the fire risk assessment of the turbine type.

They can be automatic and/or manual. The type of extinguishing agent shall be chosen for the intended type of application:

- carbon dioxide (CO_2),
- inert gases,
- fine water spray,
- water spray,

- foam,
- aerosol.

The use of agents shall be assessed and shall ensure the safety of personnel in case of an intended or unintended release.

11.5.5.2.2 Automatic discharge suppression systems

If an automatic discharge suppression system is installed, it shall be designed based on the fire risk assessment.

Automatic discharge suppression systems shall have an interface to the control system of the wind turbine and be monitored.

In the case that a suppression system is designed to cover compartments where personnel could be present, the system and the agent should be chosen so that the residual risk to personnel is acceptable.

11.5.5.2.3 Portable firefighting equipment

The wind turbine shall be equipped with manual firefighting equipment to allow personnel to clear the evacuation or escape passage or to put out a small fire.

Type, size and location should be chosen in accordance with the fire risks which have been identified by the fire risk assessment and the emergency exit locations.

11.6 Information for use

Information for use shall be given according to ISO 19353:2019, Clause 7.

12 Emergency, escape and evacuation

12.1 General requirements

12.1.1 General

The wind turbine shall be designed to allow evacuation, escape and rescue of personnel in case of an emergency. The wind turbine shall be designed to allow rescue from any workplace within the wind turbine.

The wind turbine emergency instructions shall reflect the specific product. It shall display the evacuation, escape and rescue routes as well as the equipment necessary for each potential emergency scenario.

An escape and evacuation map/plan shall be located at the entrance level and in the nacelle, displaying the evacuation and escape routes, location of firefighting equipment, first aid, etc. and the specific relevant turbine information.

All emergency routes shall be verified through physical demonstrations. Evacuation and escape routes shall be quickly and easily opened and passed. In case of rescue of an injured person, first the person shall be stabilized before transportation and it is therefore acceptable to spend some time to establish an additional rescue route (e.g., removing covers, ladders and other minor components using hand tools).

12.1.2 Evacuation and escape

Evacuation and escape could be necessary in different scenarios, mainly in case of fire. An analysis of these scenarios shall be made, and mitigations measures will be taken accordingly.

Available safe egress time (ASET) shall exceed the required safe egress time (RSET).

For the required safe egress time (RSET), the following shall be considered:

- $t_{detection}$ is the time between the beginning of the fire (usually the time zero of a time-dependent design fire) until the fire detection. It depends on the fire detection elements and their location.
- t_{alarm} is the time between the detection and alerting the exposed person, including searching and alerting colleagues in the danger zone.
- $t_{reaction}$ is the time from the triggering alert until the beginning of the preparation, the time that a person needs to realize what is happening and what to do.
- $t_{preparation}$ is the time for getting dressed in/wearing the personal protective equipment and time for preparing any equipment necessary to be able to escape/evacuate. The time shall be measured through physical demonstration.
- $t_{evacuation/escape}$ is the time between when the first person begins to evacuate/escape and when the last person reaches the place of safety or temporary safety. The time shall be measured through physical demonstration.

12.1.3 Routes

The wind turbine shall have at least 2 exits independent from each other. If evacuation or escape routes are used for other purposes (e.g., hoisting tools or materials to the nacelle) which can obstruct the route, an additional evacuation/escape route shall be provided.

The evacuation and escape routes shall be free of obstacles. They shall be marked according to 13.2.

Lighting of the evacuation and escape routes shall be designed according to the parameters set out in Clause 10.

The anchor points shall be designed according to 9.2.5.

12.1.4 Equipment

If special equipment is required to escape, this shall be permanently located in the wind turbine, near the escape point(s). This equipment shall allow the regular number of persons working simultaneously to escape in a minimum time.

If additional personnel need to be present in the wind turbine during specific tasks (e.g., installation), additional equipment for escape can be available, e. g. through organizational arrangements.

The equipment shall be chosen or designed considering:

- the specific wind turbine design,
- the hub height,
- the number of persons working simultaneously,
- the maximum number of persons allowed,
- the anchorage structures, etc.,
- the time $t_{preparation} + t_{evacuation/escape}$.

The equipment can be permanently integrated in the wind turbine or in a storage box in a fixed location and attached to the structure, so it is not loose. The equipment shall be protected from the environment and be preserved and maintained as per manufacturer's instructions.

In the case of foreseeable escape to the sea requiring survival equipment (e.g., survival suit, life vest, beacon), the turbine shall allow enough room to store and put on the equipment near the escape point(s) for the number of persons who needs to escape simultaneously. A specific assessment shall be made to determine if and which type and quantity of equipment shall be permanent in the wind turbine.

12.1.5 Escape point(s)

Escape point(s) can be inside or outside the wind turbine (e.g., hatches in vertical or horizontal direction, helihoist, floor nacelle roof).

The escape point and surroundings shall have provisions for the use of the escape equipment, e.g., anchor point for descent units. The user of the escape equipment shall be taken into consideration when designing the escape point, e.g., smoke, heat, escape equipment functionality and interfaces, air quality, scraping and swinging of the descent unit ropes.

Hatches used as escape point shall be able to stay in open position without unintended closing.

The minimum dimensions of a hatch for escape shall be 0,8 m × 0,8 m.

It shall be possible to prepare escape in a safe place (e.g., dressing in survival suit, prepare descent device).

In case of escape, provisions shall be made to escape directly without the need for climbing fences or other obstacles, unless climbing provisions are provided on both sides of the fence. It shall be possible to attach the descent device before passing the fence or the obstacle.

The access to the helihoist shall be capable of being opened from the outside and be secured in open position.

12.1.6 Verification of evacuation and escape strategy

The efficiency of the evacuation and escape strategy shall be verified by means of testing to verify that personnel are able to exit the wind turbine from any location at which they could be working to a/the place of temporary safety, within the estimated times using the prescribed route for each scenario. Mock-up turbines or part of turbines can be used for verifications. Dummy dolls can be used when carrying out tests outside the wind turbine.

If the wind turbine is intended for operation offshore, the test may be carried out onshore but exit to a place of safety shall be verified taking the offshore operating environment into consideration.

The test validation shall be accepted when it is verified that personnel can reach the place of temporary safety within the estimated times before the evacuation and escape route are compromised according to the fire risk assessment.

The most relevant scenarios shall be tested, as minimum but not limited to:

- evacuation/escape from blade to place of temporary safety,
- evacuation/escape from blade to ground/foundation or water if offshore,
- evacuation/escape upwards when a fire hazard is present at the bottom of the tower,
- set up of equipment and escape from the escape point(s)[19].

[19] Note that descent test does not need to be on an erected turbine, it can be done in a mock-up placed on the ground. The time to prepare equipment at escape point and escape free of obstacles shall be measured, however, the time to descent can be calculated to match the relevant hub height.

In carrying out the test, the number of personnel in the wind turbine shall be equivalent to the maximum number allowed. The different test scenarios shall consider the maximum number of personnel allowed in the wind turbine simultaneously. Quantification of the time required for additional personnel to escape can be done with calculation when the necessary waiting time has been measured in a test.

The test shall be carried out using only emergency lighting and personnel shall be dressed in their normal clothing and personal protective equipment if relevant.

12.2 Rescue

12.2.1 General

The wind turbine shall be designed so that personnel can be rescued in all foreseeable scenarios. The passages, doors, hatches, etc. shall accommodate the worst foreseeable scenario (e.g., horizontal rescue of a person on a transfer board).

Instructions for carrying out rescue from the different scenarios identified by risks assessment shall be made. This shall include, but is not limited to:

- blade,
- hub,
- nacelle (different areas),
- tower section,
- basement (onshore),
- sub-structure (offshore).

12.2.2 Equipment

The rescue equipment shall be chosen based on foreseen scenarios. It shall be permanently located in the wind turbine, unless operational arrangements with the same of higher level of safety are provided.

It shall have a dedicated location in the turbine and be protected from the environment.

12.2.3 Verification of the rescue strategy

The efficiency of the rescue strategy as it relates to the design of the wind turbine shall be verified by means of testing to demonstrate that personnel can be rescued from any location at which they could be working.

The test can be conducted in a real wind turbine or in a mock-up. Dummy dolls can be used when carrying out the test.

The relevant scenarios shall be tested. The success criteria of the verification are to demonstrate that the rescue can be carried out without additional risks to the rescued or the rescuers.

12.3 Adverse weather

The design limits for each turbine type regarding the weather conditions in which the maintenance can be carried out shall be identified and informed through the instructions, e.g., wind speed limits.

The wind turbine shall have a safe place for personnel to stay during a thunderstorm according to IEC 61400-24.