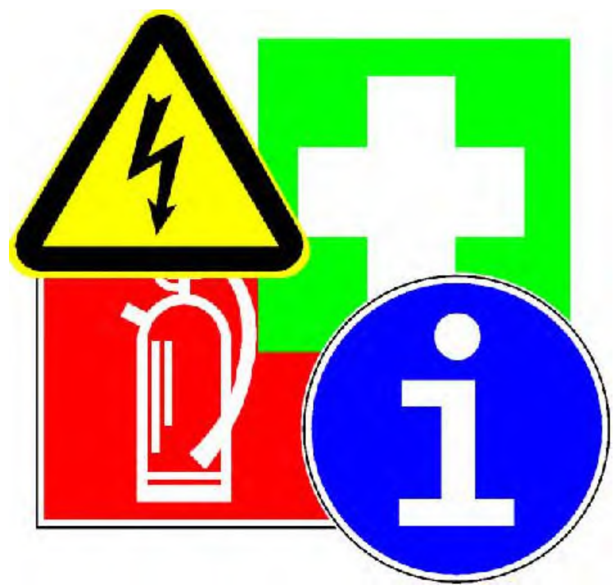
Supplemental Appendix F

Wind Energy Turbine Manufacturer Safety Manuals

Technical Documentation
Wind Turbine Generator Systems
1&2MW Platform



Safety Manual

-Please read first-

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All technical data is subject to change in line with ongoing technical development!

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1 Basic Information on the Technical Documentation for GE Energy Wind Turbine Generator Systems

This "Safety Manual" is a constituent part of the technical documentation for GE Energy wind turbine generator systems. In the case of offshore plants, the supplementary safety information for offshore plants is also to be considered.

The safety manual must be read and understood by the operating and maintenance personnel and the owner, in order to guarantee safety in and on the wind turbine generator system and to prevent accidents and personal injuries.

In addition to the safety manual, the respective specific safety information in the technical documentation, in which e.g. installation or maintenance is described, must always be read.

The basic rules of conduct for safe working in and on the WTG are described in this safety manual.

Any unclear points in the technical documentation, which may jeopardize the correct performance of work in or on the WTGS, must first of all be clarified. Contact GE Energy for advice if necessary.

In addition to the safety manual, the local safety and accident prevention regulations must be complied with to ensure the safety of personnel.

Explanation of Abbreviations

WTGS	Wind Turbine Generator System
PPE	Personal Protective Equipment
EHS	Environment, Health & Safety

2 General Safety Principles

The GE Wind Energy 1&2MW Platform Wind Turbine Generator System (WTGS) has been built according to recognized safety rules.

Hazards for the user or third parties and impairment of the wind turbine generator system and other property may nevertheless arise during the use of this facility if it is

- operated by untrained or uninstructed staff
- not used properly
- improperly maintained or serviced

The owner / operator responsible for the WTG must ensure that

- The safety manual and the operating manual are available and are complied with
- The service conditions and technical data are complied with
- The protective devices are used
- The prescribed maintenance work is carried out
- The maintenance personnel are immediately informed or the plant immediately shut down if higher temperatures, noise, vibration, etc. compared to operation at normal rating should occur.

The operating manual contains the information required for operation of the WTG by qualified personnel.

The warranty of the manufacturer is only provided if the currently valid operating manual is observed and complied with.

NOTE

Take precautions against malfunctions and thereby prevent personal injury or death and material damage!

2.1 Personnel Groups

Different personnel groups are specified for carrying out the various tasks in and on the WTG. Before work is started, it must be ensured that the personnel in question have the requisite qualifications to carry out the respective tasks. If necessary, suitable training or qualification measures are required, or the work is carried out by other personnel with a suitable qualification.

2.1.1 Qualified Persons

Work on electrical equipment and machinery may only be carried out by qualified persons who are familiar with the currently applicable safety and installation regulations. The qualified persons must be authorized to carry out the requisite tasks by the person responsible for safety in the WTG under the health and safety regulations. A qualified person is a person who

- has appropriate training and experience
- is familiar with the currently applicable standards, regulations and accident prevention regulations and generally recognized code of practice
- has been instructed in the operating principle and service conditions of electrical and mechanical drive systems and
- can recognize and avoid dangers

Unqualified persons may not be deployed.

2.1.2 Technically Competent Persons

Technically competent persons are persons who have the requisite technical knowledge for the inspection of work equipment as a result of their professional training, their professional experience and their current professional activity.

2.1.3 Experienced Persons

An experienced person is someone who, on the basis of his technical training and experience, has gained adequate knowledge in the particular field of the equipment/device to be tested and who is acquainted with the pertinent national industrial safety legislation, the regulations for the prevention of accidents, directives and generally accepted engineering standards (DIN standards, VDE regulations, technical rules of other member states of the European Union or other contracting states of the agreement concerning the European Economic Area as well as OSHA/ANSI/NFPA/CSA and other standards and regulations for the Americas) to the extent that he is able to assess the safe working order of the equipment/device concerned.

2.1.4 Experts

Experts are persons who are familiar with the relevant industrial safety regulations, directives and generally recognized code of practice and can verify and authoritatively assess the presence of threats and dangers.

2.2 Proper Use

The GE Energy 1&2MW Platform Wind Turbine Generator Systems are intended solely for the generation of electrical power by means of wind energy.

Any other use or use extending beyond this is deemed to be improper. The operator / owner of the WTG bears the sole responsibility for any damage resulting there from.

The same also applies to any unauthorized modifications made to the WTG. As a general principle, modifications to the WTG may be carried out only after consultation with GE Energy, in order to guarantee the safety and the correct functioning of the WTGS.

Proper use also includes compliance with the information on

- Safety
- Operation
- Service and maintenance

provided in the technical documentation of the WTGS.

2.3 General Information

The wind turbine generator system may only be used in a technically perfect condition in line with the technical documentation. In addition, it must be used as intended, as well as with safety in mind and with an awareness of the dangers. Any malfunctions, particularly those which could impair safety, must be reported and remedied immediately.

Anybody who has been authorized to carry out erection, commissioning, operation or maintenance work must have read and understood the complete operating manual, in particular the safety manual.

It is too late to read the manual while carrying out the work. This applies especially to personnel who are only occasionally deployed on the wind turbine generator system.

The operating manual must be readily available at the site of operation of the wind turbine generator system at all times. It is kept in the main cabinet of the WTG.

The relevant regulations for the prevention of accidents (see "Information for the Operator" in "Basic information regarding the operating instructions manual") and any other generally recognized safety and industrial health regulations must also be complied with.

We cannot be held liable for any damage or accidents as a result of non-compliance with the operating instructions, the relevant regulations for the prevention of accidents and any other generally recognized safety and industrial health regulations.

Responsibilities for the different activities within the framework of operation, service and maintenance of the WTG must be clearly defined and complied with. This is the only way to prevent mistakes, particularly in dangerous situations.

The instructions for

- Shutting down the WTG
- Maintenance work
- Handling the rotor lock
- Entering the rotor hub

must be followed during the inspection, maintenance and repair of the wind turbine generator system and the safety devices.

3 Marks, Signs and Symbols

3.1 Danger Classifications and Symbols

The following danger classifications and symbols are used in the technical documentation for the GE Energy 1&2MW Platform wind turbine generator systems:

NOTE

Notes include user tips and useful information.
All notes should be implemented in the interest of a proper use of the wind turbine generator system.

ATTENTION

Exact description of danger!

Indicates a potentially hazardous situation that may result in damage to the WTGS or surrounding area if the dangerous situation is not avoided.

Gives are clear instruction on how to avoid damage to the WTGS.

CAUTION

Exact description of danger!

Indicates a potentially hazardous situation which may result in slight or minor injury if the dangerous situation is not avoided.

Gives a clear instruction on how to avoid the dangerous situation.

WARNING

Exact description of danger!

Indicates a potentially hazardous situation that may result in death or serious injury if the dangerous situation is not avoided.

Gives a clear instruction on how to avoid the dangerous situation.

DANGER

Exact description of danger!

Indicates an imminent threatening danger resulting in death or serious injury.

Gives a clear instruction on how to avoid injury.

All notices and symbols directly attached to the WTG, such as safety signs, operating notices, rotation arrows, component identification markings, etc., must be observed without fail. They may not be removed and must be maintained in a fully legible condition.

3.2 Marks and Signs attached by GE Energy

The personnel in the WTG must be able to check certain data at all times, in order to ensure safe operation of the WTG. The following information must therefore be clearly visible and permanently attached:

1. Marks for identification of the device
2. Characteristic values by means of which the permissible limits for safe use are specified, e.g. permissible load, rotational speed, pressure.

In addition, information about the prescribed use and about possible dangers which could arise when handling a device must be provided.

Safety marks could be texts, signs, signals, pictographs and colors. All texts are to be in two languages, i.e. English and the respective national language. Pictographs must be easy to understand and self-explanatory.

The signs are made of durable materials with stable colors.

The instructions on the safety signs and marks must be followed.

The presence and legibility of the safety signs must be checked as part of the regular maintenance work. Any missing or illegible safety signs must be replaced immediately.

The signs in the wind turbine generator systems may differ as a result of country-specific differences in the environmental and safety regulations.

All possible signs attached by GE Energy are listed in the following:

3.2.1 Tower

Keep escape and rescue routes clear!

This sign is attached in the entrance area of the turbine.

Not for USA/Canada!

It is strictly forbidden to leave the WTGS with rotor lock applied!

This sign is attached in the tower at the bottom of the ladder.

Falling hazard warning on trap doors and floor openings!

This sign is attached to each platform.

Falling objects hazard warning!

This sign is attached to each hatch.

Admissible maximum loading of the platform!

This sign is attached to each platform.

Always close hatch after climbing through! This sign is attached to each platform.	
Climbing the WTG - Things to do! This sign is attached in the tower near the ladder.	
Danger: Electricity! This sign is attached to the outside of the door..	
Dangerous batteries! This sign is attached to the emergency power supply unit and to the main cabinet.	

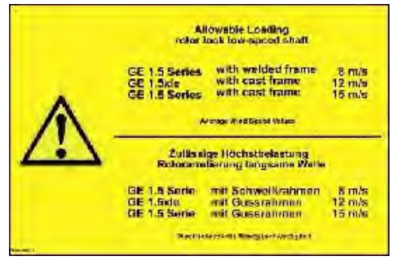
Attention, confined space! This sign is attached to the underside of the access hatch leading to the transformer section.	
No access for persons with pacemakers!	
Fire extinguisher! This sign is attached in the tower near the fire extinguisher. Not for USA/Canada!	
ONLY WITH TRANSFORMER IN TOWER: **Attention! High voltage!** This sign is attached to the outside of the door, the switch gear, the transformer cage and the hatch to the tower base.	

Access forbidden! This sign is attached to the outside of the door.	
First Aid! This sign is attached at the bottom of the tower. Not for USA/Canada!	
First Aid! This sign is attached at the bottom of the tower. Not for USA/Canada!	

Climbing the WTG - Things not to do! This sign is attached in the tower at the bottom of the ladder.	
Tie off point Only for USA/Canada!	

3.2.2 Nacelle

Description	Sign
Pinch Point (ANSI) This sign is attached in the nacelle during the assembly. Only for USA/Canada!	
Pinch Point (ISO) This sign is attached in the nacelle during the assembly. Only for USA/Canada!	
Instructions for working in the nacelle! This sign is attached in the nacelle.	
Instruction for the rotor lock on the high-speed shaft! This sign is attached to the cover beside the rotor lock on the high-speed shaft (sample: actual wind speed limits may vary by WTG model in accordance with the Assembly and Maintenance Wind Speed Limitations document).	

Description	Sign
Allowable Loading rotor lock - low-speed shaft! This sign is attached to the rotor lock of the low-speed shaft. This sign shown here is a representative example; versions with the updated wind speeds for newer models may be applied.	
It is forbidden to leave the WTGS with rotor lock applied! This sign is attached in the nacelle above the passage to the tower.	
Standing on the starter terminal box prohibited – NOT A STEP! This sign is attached to all surfaces which may not be used as a step.	
Warning: strong wind currents! This sign is attached to the hatch leading to the roof of the nacelle (exit to the hub).	
Falling Hazard Warning! This sign is attached to the hatch leading to the roof of the nacelle (exit to the hub).	
Caution! Hot surface. This sign is attached to the generator.	

<table>
<tr><th>Description</th><th>Sign</th></tr>
<tr><td>

ONLY FOR PLANTS WITH COLD WEATHER EQUIPMENT!

Caution! Hot surface.

This sign is attached to the anemometer on the roof of the nacelle.

</td><td>

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<tr><td>

Instructions for entering the rotor hub!

This sign is attached to the hatch leading to the roof of the nacelle (exit to the hub).

</td><td>

</td></tr>
<tr><td>

Instructions for yaw stop!

This sign is attached beside the yaw stop switch on the uppermost tower platform.

</td><td>

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<tr><td>

ONLY FOR PLANTS WITH AN "EMERGENCY DESCENT HATCH":

Falling hazard at hatches!

This sign is attached to the optional emergency descent hatch.

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</table>

<table>
<tr><th>Description</th><th>Sign</th></tr>
<tr><td>

Maximum load on the bottom surface in the nacelle enclosure!

This sign is attached in the nacelle enclosure near the generator.

</td><td>

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<tr><td>

Warning! Must be tied off at all times!

This sign is attached to the hatch leading to the roof of the nacelle (exit to the hub).

Only for USA/Canada!

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<tr><td>

Attention! Danger from rotating parts!

This sign is attached to the yaw and the low-speed and the high-speed shaft.

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<tr><td>

Fire extinguisher!

This sign is attached in the nacelle near the fire extinguisher.

Not for USA/Canada!

</td><td>

</td></tr>
<tr><td>

ONLY FOR PLANTS WITH AN "EMERGENCY DESCENT HATCH":

Emergency exit!

This sign is attached above the emergency descent hatch!

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</td></tr>
<tr><td>

First Aid!

This sign is attached near the First Aid box.

Not for USA/Canada!

</td><td>

</td></tr>
</table>

Description	Sign
First Aid! This sign is attached near the First Aid box. Not for USA/Canada!	
First Aid! This sign is attached near the First Aid box. Not for USA/Canada!	
Use the railing for hooking! This sign is attached beside the roof hatch in the nacelle enclosure. Not for USA/Canada!	

Description	Sign
Attention! Use the railing for hooking! This sign is attached beside the roof hatch in the nacelle enclosure. Only for USA/Canada	
Hook onto Spinner! This sign is attached to the hatch leading to the nose cone. Not for USA/Canada!	
Hook onto Spinner! This sign is attached to the hatch leading to the nose cone. Only for USA/Canada	
Lift point (ANSI) This sign is attached to the lifting lugs of the main frame. Only for USA/Canada	
Lift point (ISO) This sign is attached to the lifting lugs of the main frame. Only for USA/Canada	
Lift point for top cover only (ANSI) This sign is attached to the tie-off points of the top cover. Only for USA/Canada	

Description	Sign
Lift point for top cover only (ISO) This sign is attached to the tie-off points of the top cover. Only for USA/Canada	

3.2.3 Hub

Description	Sign
Dangerous batteries! This sign is attached to the battery cabinet in the hub.	
Attention! Danger from rotating parts! This sign is attached to the pitch drive mechanisms.	
Danger: Electricity! This sign is attached to the axis cabinets in the rotor hub.	
Falling Hazard Warning! This sign is attached to the hatches of the hub.	
Maximum load on the blade root bulkhead This sign is attached above and below each rotor blade connection, so that the signs are exposed to view on entering the rotor blade.	

Description	Sign
Attention! Confined space This sign is attached to the access hatch leading the hub.	
Caution! May energize without warning (ANSI) This sign is attached to the pitch drive mechanisms. Only for USA/Canada	
Caution! May energize without warning (ISO) This sign is attached to the pitch drive mechanisms. Only for USA/Canada	
Secure hatch (ANSI) This sign is attached to the access hatch to the hub Only for USA/Canada	
Secure hatch (ISO) This sign is attached to the access hatch to the hub Only for USA/Canada	
Caution! Handle or Step only (ANSI) This sign is attached to the handles in the entrance to the hub. Only for USA/Canada	
Caution! Handle or Step only (ISO) This sign is attached to the handles in the entrance to the hub. Only for USA/Canada	

4 Information for the Operator/Owner of the Wind Turbine Generator System

The operator of the WTG is responsible for ensuring that no unauthorized persons remain inside or on the WTG. The WTG must be kept locked to prevent this.

The wind turbine generator system may only be started up if it has been completely assembled and is in working order.

The wind turbine generator system may only be operated if all safety equipment and safety-relevant devices, e.g. detachable protective equipment, are in place and operational.

If any malfunctions occur or if ice builds up on the rotor blades, the wind turbine generator system must be shut down immediately and secured. Malfunctions are to be remedied without delay by trained technical personnel.

In the case of malfunctions which are not automatically reset by the control system of the WTG, GE Energy must be contacted before a restart is carried out, in order to confirm that the WTG may be placed in the automatic operating mode (i.e. whether the WTG may be restarted).

Follow the switch-on and shut-down procedures and take note of the visual and monitoring displays in accordance with the operating manual!

In addition to this, the operator/owner of the WTG must comply with the following additional safety instructions (if maintenance is not carried out by GE Energy employees):

- If the WTG is not directly connected to the public telephone system, the maintenance personnel must have a cell phone or radio with them when ascending the tower.
- The personnel must be informed about who to contact in an emergency. (Telephone numbers of a rescue center, police, fire department…)
- For safety reasons, the personnel must be instructed that the WTG may only be entered by a minimum of two persons.
- Special authorization from GE Energy is required to carry out inspection and maintenance work inside a WTG while it is in operation.
- The personnel must be instructed to keep the WTG escape routes clear at all times when carrying out work as a part of maintenance or operation.
- In the case of work involving a fire hazard, the personnel must have a fire extinguisher ready at hand, in order to be able to immediately extinguish any fire that may start.
- Personnel are not permitted to remain at a higher level in the WTG while work involving a fire hazard is being carried out.
- Personnel instructed to carry out work in or on the WTG must be provided with instructions and the appropriate personal protective equipment (PPE).
- The WTGS must only be entered when a second person is available to provide assistance or call for help in case of accident.

- If the WTG is part of a wind farm and connected to a wind power plant, this safety manual must be supplemented in cooperation with the local power supply company, so that it also:
  - describes the safety aspects relevant to the wind farm
  - describes the exchange of information and names the persons who are to be contacted
  - describes access to basic first aid facilities

5 Signs to be attached by the Operator/Owner

The operator/owner of the WTG is obliged to attach additional warning signs to the WTG. These are intended to cover safety aspects which are not related to the scope of supply of the manufacturer of the WTG.

The warning signs must state that

- It is dangerous and prohibited for unauthorized persons to enter or climb the WTG
- It is prohibited to remain in the vicinity of the WTG while work is being carried out outside the nacelle
- Deposits of ice which have formed on the rotor blades (depending on the location of the WTG) could drop off

The operator/owner is responsible for seeing that any components or plant components which he has supplied are properly equipped with signs.

6 Safety Equipment

The safety equipment serves to reduce risks and dangers. You will find further information on equipment and items which are subject to inspection in the annex of this safety manual.

6.1 Personal Protective Equipment

Everybody must wear Personal Protective Equipment (PPE) when working on or in the WTG to protect themselves from injury.

DANGER

Danger of accident!

Never enter or climb the WTG without the personal protective equipment. Otherwise there is danger of injury and falling.

The PPE is especially required for climbing the tower. It comprises:

- Safety harness
- Cable or rail grab device/fall arrestor
- Double lanyard with shock absorber
- Hard hat
- Safety boots
- Gloves
- Safety glasses
- Hearing protection (if required)
- Respirator (if required)
- Thermal clothing (if required
- Suspension trauma straps

The PPE must be of an approved type; must be compliant with the applicable local regulators; and must bear marks of conformity stating that it is suitable for the work and protection involved and that it is also suitable for the climatic conditions at the site of the WTGS.

NOTE

The extent and the equipment of the personal protective equipment may vary in some countries. Please comply with the local regulations!

Optionally, safety harness and travelling safety hooks may be supplied by GE Energy. The remaining constituents of the PPE are not part of the scope of supply of the wind turbine generator system. If supplied the safety harnesses and travelling safety hooks must be properly stored in the WTG and must be accessible.

If several persons ascend the tower simultaneously, personal protective equipment must be available for the respective number of persons.

NOTE

Check the completeness, the condition and the function of your personal protective equipment in good time before entering the WTG. If a piece of the equipment is missing, it must be replaced before starting work.

The safety harness and the entire safety equipment must be checked before use. Damaged equipment must never be used.

The PPE must be inspected and tested by a technically competent person after any fall, or at the intervals recommended by the manufacturer at least.

NOTE

Follow the manufacturer's directions for use for all component parts of the personal protective equipment!

6.2 Safety Harness

ATTENTION

Danger of equipment failure.

The Safety harness and all safety equipment should never be exposed to acids/caustic chemicals. If this is unavoidable, follow manufacturer instructions for treatment.

Protect from sharp edges and sharp-edged objects.

Wash and dry according to manufacturer's instructions.

Store in a well-aired place out of direct sunlight.

The safety harness is used to protect personnel during the ascent to the nacelle of the WTG, during the descent from the nacelle of the WTGS and, in combination with a lanyard and a shock absorber, when carrying out work in areas where there is a danger of falling.

Optionally, safety harness and travelling safety hooks may be supplied by GE Energy.

The safety harnesses and the entire safety equipment must be cleaned, cared for, maintained and stored in accordance with the manufacturer's instructions.

Follow the manufacturer's instructions when putting on the safety harness.

6.2.1 Example of Putting on a Standard Safety Harness

As previously mentioned, the manufacturer's instructions should always be followed when putting on a safety harness. An example of how to wear a safety harness is included below.

1. **Hold the safety harness in such a way that you can see in which way it is going to be put on at a later stage.**
   (Fig. 1)
   Ensure that the loops are not twisted.

Fig. 1: Preparing the safety harness

2. **Insert your arms through the yellow shoulder straps and place the safety harness on your shoulders like a rucksack.**
   (Fig. 2 and Fig. 3)

Fig. 2: Insert your arms through the shoulder straps

Fig. 3: Safety harness on the shoulders

3. Closing the stomach strap

Take the two loops positioned at stomach height.

Pull the right-hand loop (1) through the eyelet (2) and guide the end of the loop through the rectangular frame (3). (Fig. 4)

Adjust the strap to ensure a close fit.

Fig. 4: Closing the stomach strap

4. Closing the chest strap

Take the two straps positioned at chest height. (Fig. 5)

Pull right-hand strap (1) through the eyelet (2) and insert its end through the rectangular frame (3) also located on the right-hand strap.

Adjust the strap to ensure a close fit. (Fig. 6)

Fig. 5: Closing the chest strap

Fig. 6: Closed chest strap

5. **Closing the leg loops**

   Push both loose leg loops from behind through the legs and to the front.

   Pull the leg loops through the strap closure and pull the leg loops tight. (Fig. 7)

Fig. 7: Closing the leg loops

6. **Check that all straps are straight and close fitting and that the buckles are closed correctly.** (Fig. 8)

Fig. 8: Safety harness correctly fitted

6.2.2 Cable or Rail Grab Device/Fall Arrestor

The manufacturer's instructions for use of cable or rail grab device are to be followed.

In combination with the safety harness, the cable or rail grab device is a safety device for ascending/descending the tower via the ladder. Should somebody slip off the ladder, the cable or rail grab device clamps on tightly to the safety rail and prevents a fall. The system consists of a fixed guide, fastening elements, and a travelling arrestor device. A steady straight-line ascent and descent of the ladder without the user leaning back in the harness is best way to ensure that the travelling safety hook runs freely.

WARNING

Beware of hand injuries!

A free running travelling safety hook can crush your hands if you grasp the device or the safety rail or cable.

Keep your hands on the sides of the ladder during the ascent/descent.

Using the Cable or Rail Grab Device

Rail Grab Device

1. Insert the travelling safety hook into the retaining eyes of the safety harness.
2. Push the travelling safety hook into the guide rail mounted on the ladder.
3. Ascend and descend the ladder slowly and carefully.

Fig. 9

Cable Grab Device

1. Insert the cable grab fall arrestor and the shock pack assembly into the D-ring (or retaining eyes) of the safety harness.
2. Push the cable grab fall arrestor into the wire rope attached to the ladder.
3. Ascend and descend the ladder slowly and carefully.
4. Ensure to be in contact with the ladder on at least 3 points at all times.

Fig. 10

6.3 Protective Equipment for Measurements on Live Components

DANGER

Danger! Electricity!

Contact can cause extremely serious injuries and even death.

Life-threatening hazard!

Special PPE is required for measurements on live components. This provides protection against electricity flowing through the body, e.g. as a result of touching live components in operation. Furthermore, it provides protection against accidental arcs caused by insulation breakdowns e.g. as a result of switching operations under load.

Refer to NFPA 70E document (GE Standard) for further guidance on PPE requirements for electrical work.

6.4 Hooking Points

As a rule, the hooking points are marked in yellow and are designated with a statement of the permissible safe work load. These hooking points are to be used with a safety harness and lanyard with a shock absorber to provide protection in areas where there is a danger of falling.

ATTENTION

Exchange of the rail

The nose cone rail and nacelle rail must be exchanged after any fall!

6.5 Abseiling Device

Not all wind turbine generator systems are supplied with an abseiling device. There is sometimes only a certain number of devices, especially in larger wind farms.

The abseiling device (e.g. abseiling device AG 10 K – RK Sicherheitstechnik) has a rope which is long enough for the respective height of the tower of the WTG.

The abseiling device is stored in a lead-sealed equipment bag, which is located in a net beside the hatchway to the roof of the nacelle.

Fig. 11: Equipment bag in the net

The abseiling device is used by the personnel to abseil from high workplaces. It is not a fall arresting device, instead it is used primarily for the evacuation of personnel in the event of an accident or fire. In case of fire, it can be used to abseil from the roof of the nacelle of the WTG as a 2nd escape route.

As a rule, the hooking points for the abseiling device are marked in yellow and are designated with a statement of the permissible safe work load. The abseiling device is attached to the hooking point by means of a snap hook or to the roof rail by means of a sling rope and a snap hook.

ATTENTION

Danger of accident with a defective abseiling device!

In an emergency, your life could depend on the abseiling device working properly!

As a result, check the integrity of the seal of the equipment bag on each visit to the nacelle. The abseiling device is pre-assembled and is ready for use immediately after it has been removed from the equipment bag.

Carry out an additional visual inspection of the abseiling device immediately before use.

NOTE

It is easy to operate the abseiling device incorrectly in emergency situations. As a result, ensure that you know how to operate the device and are familiar with the abseiling operation. Please also read the operating manual.

This is the only way to ensure that the correct maneuvers are carried out in an emergency.

6.5.1 Abseiling from the Roof of the Nacelle

Abseiling can take place individually or in pairs. The abseiling device may be loaded with a maximum of 225 kg up to a rope pitch of 100 m. Abseiling takes place at a speed of 0.7 m/s. The abseiling speed is regulated by means of a centrifugal brake.

A typical abseiling operation is described in the following. The procedure described may vary depending on the abseiling device. As a general principle, always follow the instructions of the manufacturer of the respective abseiling device!

1. **Make sure that your safety harness is put on correctly.**
2. **Secure yourself against falling by means of the lanyard. Attach the lanyard to tie-off points or nacelle rail. Step out on the roof of the nacelle.**
3. **Close the roof hatch.**
4. **Break the lead seal on the equipment bag.**
5. **Remove the abseiling device from the equipment bag.**

   Leave the rope in the equipment bag.
6. **Attach the abseiling device to the roof rail of the nacelle by means of the sling rope and the snap hook.**
7. **Secure the snap hook with the clamping nut.**
8. **Throw down the equipment bag with the rope.**
9. **Check the condition and the correct functioning of the device.**
10. **Check the rope for loops and knots.**

Fig. 12: Abseiling device

DANGER

Interruption of abseiling through loops or knots!

Loops or knots in the rope prevent abseiling, since the rope cannot run through the abseiling device if it has a knot. As a result, always check the rope carefully!

REMOVE ALL LOOPS AND KNOTS FROM THE ROPE BEFORE YOU START ABSEILING!

11. **Hook the snap hook on the short end of the rope into the two chest rings of your safety harness.**
12. **Sit in front of the roof rail on the edge of the nacelle.**
13. **Ensure that the length of rope between the chest rings of your safety harness and the abseiling device is pulled taut.**
14. **Release the lanyard attached for your safety.**
15. **Slowly put your weight on the rope of the abseiling equipment.**

    After you have let go of the nacelle and the roof rail, you will abseil at a speed of 0.7 m/s.
16. **After you have reached the ground, immediately release the snap hook from the chest rings of your safety harness.**
17. **A second person waiting on the roof can then hook in the snap hook of the end of the rope which is now at the top and abseil as described.**

    The rope may have to be pulled through until the snap hook arrives at the top.
18. **The device must be inspected by a technically competent person after a rescue or an abseiling exercise.**

6.5.2 Care and Maintenance of the Abseiling Device

The textile components of the abseiling equipment may only be cleaned by the manufacturer.

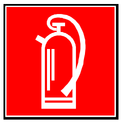
If damage to the rope, snap hook or abseiling device is discovered, the escape equipment must be withdrawn from use and inspected by the manufacturer.

Under normal service conditions, a service period of 4-6 years can be assumed for the textile ropes.

The abseiling device must be inspected by a technically competent person or by the manufacturer after a rescue or an abseiling exercise or at the intervals recommended by the manufacturer at the latest.

6.6 Fire Extinguishers (optional feature)

Fire extinguishers are optional in the wind turbine generator systems (WTG). If fire extinguishers are supplied, the WTG is normally provided with a fire extinguisher in the tower and in the nacelle.



The locations of the fire extinguishers are identified by this sign.

DANGER

Danger: Electricity!

De-energize the installation before using the fire extinguisher.

After actuation of the medium-voltage circuit-breaker, keep a safe distance of at least one meter from the fire when extinguishing!

The fire extinguisher may only be used on electrical installations up to 1000V!

NOTE

Ensure that you are familiar with the function and the operation of the fire extinguisher. Only thus can you act quickly and purposefully in emergency situations.

The use of fire extinguishers must be practiced. The personnel deployed in the WTG must therefore be trained in fire-fighting at regular intervals.

The fire extinguishers must be regularly inspected by a technically competent person in accordance with the national regulations. A record of the check with the date must be permanently affixed to the appliance in an easily visible location. The directions for use (on the fire extinguisher) must be followed before fire-fighting.

6.6.1 Operating principle of the optional fire extinguisher – An example

As a general principle, always follow the instructions of the manufacturer of the respective fire extinguisher.

1. **Remove the safety tab (1).**
2. **Press down the fire-extinguishing button (2).**
3. **The perforating disk of the CO_2 cylinder (3) is opened and the CO_2 released for charging the tank. The appliance is ready for use.**
4. **The extinguishing agent, which is under pressure, flows through the riser pipe (4) to the valve armature.**
5. **After the fire-extinguishing button has been pressed, the extinguishing agent flows through the hose line to the spray fog nozzle (5).**
6. **The jet of extinguishing agent can be interrupted at any time by releasing the fire-extinguishing button.**

   (Contents of the fire extinguisher: 5 kg)

Fig. 13: Fire extinguisher - An example

6.6.2 Types of Fire Extinguisher

		Substances to be extinguished			
		Solid, glowing substances	Liquid substances or substances becoming liquid	Gaseous substances, also under pressure	Flammable metals (use only with a powder nozzle)
Types of Fire Extinguisher	Dry powder extinguisher with ABC dry powder	+	+	+	-
	Dry powder extinguisher with BC dry powder	-	+	+	-
	Dry powder extinguisher with metal fire powder	-	-	-	+
	Carbon dioxide fire extinguisher	-	+	-	-
	Water extinguishers (also with additives, e. g. wetting agent, antifreeze or corrosion inhibitor)	+	-	-	-
	Water extinguishers with additives which also extinguish liquid substances or substances becoming liquid in combination with water	+	+	-	-
	Foam extinguisher	+	+	-	-

6.7 First Aid

First aid is used for the initial treatment of an accident victim until the arrival of a doctor or until transport to a hospital, in order to avert a life-threatening situation or to prevent secondary injury.

NOTE

There is a legal obligation to carry out rescue measures provided that this is possible without considerable self-endangerment.

The plant may never be entered alone, so that a second person can send an emergency call. If the interphone has a landline connection, the emergency call can be made via the interphone. An operational cellphone is to be carried at all times, in order to be able to ensure rapid assistance in an emergency.

Proceed as follows in the case of an accident:

1. **Keep CALM!**
2. **In the case of serious accidents and injuries, notify a rescue center by interphone, cell phone or radio.**
3. **Render first aid immediately.**
4. **Secure the scene of the accident.**
5. **Report all accidents (near-accidents, minor accidents, serious accidents) to your immediate supervisor. Also notify the EHS department of GE Energy.**

ATTENTION

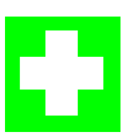
Keep access to the WTG clear!

The access roads to the plant must be kept clear at all times and be negotiable by car, in order to guarantee rapid and problem-free first aid in an emergency.

First Aid Box (Optional)

The provision of wind turbine generator systems (WTGS) with first aid boxes is optional.

If provided a first aid box is located in the nacelle of the wind turbine generator system for the treatment of minor injuries. Any material removed is to be replaced immediately after use.



This sign identifies the location of the first aid box in the nacelle.

7 Safety Devices

The safety devices of the WTG comply with the requirements of the following standards:

- DIN EN ISO 13857: 2008 - 06 – Safety distances to prevent danger zones from being reached by the upper limbs and lower limbs.

The unauthorized removal or the overriding (by-passing) of safety devices is a punishable offence. Any liability claim is invalid in the case of damage.

Any point at which danger can arise and all drive units are provided with protective covers, which can only be undone and removed by means of tools. These protective covers may only be removed by qualified staff and only for the performance of service and maintenance or repair work. The protective covers are to be refitted immediately after completion of the work.

The owner / user of the WTG and the personnel deployed by him for operation, maintenance and repairs bear the responsibility for an accident-free work process.

7.1 Emergency Stop Pushbuttons

Any power-operated work equipment with dangerous movements must have one or - if necessary - several emergency control units for the prevention or reduction of an imminent or arisen danger, by means of which the dangerous movements can be stopped or rendered ineffective in another manner.

The emergency stop pushbuttons are not dependent on electronic logic.

Emergency stop pushbuttons (red mushroom pushbutton on a yellow base) are located on the control cabinet, the top box in the nacelle and the control cabinet in the hub.

Fig. 14: Emergency stop pushbutton

NOTE

The EMERGENCY STOP pushbutton may only be pressed in situations, in which the safety of personnel or the WTGS and its components is threatened.

Pressing the emergency stop pushbutton causes the safety chain to open, and the rotor of the WTG is brought to a standstill via emergency braking. Initiation of the safety chain causes the rotor blades to travel to the feathering position in the [emergency] battery mode! In addition to this, the WTG is de-energized except for the control voltage.

7.2 Rotor Lock

The GE 1&2MW Platform plants are equipped with two rotor locks. Depending on the model of turbine being serviced and weather conditions, the permissible wind speed to engage each lock will vary. Reference the "Assembly & Maintenance Wind Speed Limitations" (General_Description_1-2MW-xxHz_WindSpeedLimitations) document for the specific wind speed limits for each wind turbine model type.

The current wind speed can be read on the SCADA display.

7.2.1 Rotor Lock on the High-speed Shaft (HSS)

The rotor lock on the high-speed shaft is located on the brake disk of the outgoing shaft of the gearbox. It must be engaged during all regular maintenance work on the drive train and for the physical inspection of the rotor hub.

Maintenance work in the rotor hub or on the drive train may only be carried out with the high-speed shaft engaged. The rotor lock on the low-speed shaft must not be engaged.

If the turbine is unable to idle after a malfunction, the lock on the high-speed shaft must be engaged. It must be ensured that all three rotor blades are in the feathering position.

Engaging the Rotor Lock on the High-Speed Shaft

1. Manual stop and pitch blades to 85° (feathered)
2. Pull out the spring loaded locking pin of the rotor lock to enable the crank mechanism and advance the rotor lock as far as possible
3. If necessary, briefly actuate/release the "rotor brake" by the switch on the top box, in order to disengage the brake for a short time, thereby placing the brake disk in a better position.
4. Fully engage the rotor lock until the locking pin locks home again at the lower position.

7.2.2 Rotor Lock on the Low-Speed Shaft (LSS)

A lock is located on the rotor shaft flange of the low-speed shaft. This is only used for carrying out special work on the drive train as defined in the maintenance manual or specific work procedure. A sliding block or a sliding bolt which is guided in a fixture on the base frame is pushed onto the shaft flange in grooves or holes. The limit switch in the safety loop is opened as a result.

Engaging the Rotor Lock on the Low-speed Shaft

1. Manual stop and pitch blades to 85° (feathered)
2. Position the rotor to align the locking bolt with flange hole
3. Engage the rotor lock on the high-speed shaft
4. Actuate the service switch to disconnect the battery in the rotor hub
5. Engage the rotor lock on the low-speed shaft
6. If necessary, release the lock on the high-speed shaft after leaving the hub.

If the wind speed unexpectedly increases beyond the allowable limits the rotor lock must be disengaged except in the event that the hub adapter joint is inadequate. If the hub adapter joint is not fully tightened to the seating torque (for torque and angle joints) or to the final torque (for torque only joints) the rotor lock must remain engaged. In this event the turbine and surrounding area must be evacuated until wind speeds return to allowable limits.

ATTENTION

Leaving the WTG with the rotor lock applied is strictly prohibited!

8 Residual Risks

Even if all the safety requirements are complied with, a residual risk remains during operation of the GE Energy 1&2MW Platform wind turbine generator systems.

Anyone who works on and with the WTG must be aware of these residual risks and follow the instructions which prevent these residual risks from resulting in accidents or damage.

DANGER

Danger of injury during ascent!

A full-body safety harness must be worn and attached to the fall arrest system during the ascent of the turbine, in order to prevent the person from falling. Any oil or grease deposits on the ladder must be removed immediately to prevent anyone from slipping while using the ladder.

Ensure that your footwear is clean!

Life-threatening hazard - working under suspended loads!

Never stand under suspended loads.

Danger of falling from the nacelle!

The nacelle has a roof hatch for accessing the hub. You may be exposed to strong winds when climbing out through the hatch. Attach your lanyard to the outside rail from inside the nacelle. Climbing out is only allowed at wind speeds up to 15 m/s.

WARNING

Falling objects hazard warning!

An object may be unknowingly and unintentionally dropped and hit and cause injury to somebody.

For this reason, only one person at a time may climb a section of the ladder between two platforms. The hatch covers must be closed again immediately after they have been passed through.

Tools and equipment must be secured while climbing and transitioning to the nacelle roof or the hub.

NOTE

As a general principle, there is a falling hazard at all higher locations / workplaces.

8.1 Special Dangers – Electric Power

Note the following rules when carrying out any work on the electrical components of the plant, e.g. assembly, connection, opening of a device, maintenance:

1. DISCONNECTION
2. SECURE against re-connection, following proper Lock Out/Tag Out (LOTO) procedures
3. Ascertain safe isolation from supply
4. Ground and short-circuit
5. Cover up adjacent live components or provide them with barriers

In addition, ensure that all drives are at standstill.

DANGER

Caution! Danger from electrical voltage!

When switched on, electrical installations and machinery have live exposed conductors or rotating parts. They could therefore cause personal injury or death and material damage if the cover and the prescribed safety devices are removed, or in the event of incorrect handling and maintenance and in the case of improper use. The above stated safety regulations must therefore be complied with, particularly when removing a cover.

In addition to this, electrical energy is still present in devices with power electronics even after the supply voltage to the device has been switched off. These devices are secured against unauthorized access. After waiting an appropriate time for the device to discharge (e.g. capacitors), always check for residual voltage before starting work.

FOLLOW THE RESPECTIVE LOCKOUT/TAGOUT INSTRUCTIONS! (cf. Chapter 13).

In the case of malfunctions of the energy supply of the wind turbine generator system, actuate the EMERGENCY STOP button immediately if the plant has not already been switched off by the automatic control system.

Only use original fuses with the prescribed amperage!

In the case of repairs, care should be taken that design features are not modified, so that safety is compromised (e.g. leakage distances and sparking distances in air) and that distances are not reduced by insulation materials.

As a general principle, maintenance work may only be carried out by two persons, so that the second person can actuate the EMERGENCY STOP button in an emergency.

Only use insulated and approved tools.

The control system and interlocking as well as the monitoring and protective functions (thermal motor protection, speed monitoring, over current, fault to ground, etc.) may not be set out of function, even during a test run.

8.2 Special Dangers – Hydraulic System

For maintenance work on the hydraulic system, maintenance staff must be completely acquainted with the hydraulic circuit diagram and must have been instructed about its function and the possible consequences of an operating error.

Prior to any work on the hydraulic accumulators, it must be ensured that the accumulator circuits have been depressurized. The shut-down device is clearly marked and independent of the system management.

DANGER

Danger through stored residual hydraulic energy!

FOLLOW THE RESPECTIVE LOCKOUT/TAGOUT INSTRUCTIONS! (cf. Chapter 13)

8.3 Special Dangers - Noise

The A-weighted equivalent continuous sound intensity level in the tower and the nacelle exceeds the permissible 70 dB(A) (per European Standard EN 50308) or the permissible 85 dBA TWA (per OSHA 29 CFR 1910.95) during operation. For some work, it may be necessary to place the WTG in operation or carry out a test run while personnel are in the nacelle.

Anybody carrying out work in the tower or the nacelle when the WTG is in operation must wear hearing protection with an appropriate level of noise protection as part of their personal protective equipment.

8.4 Special Dangers - Icing

8.4.1 Ice Build-up on the Rotor Blades

Ice build-up on wind turbine generator systems (WTG) and, in particular, the shedding of ice from rotor blades can lead to problems if wind turbine generator systems are planned in the vicinity of roads, car parks or buildings at locations with an increased risk of freezing conditions, unless suitable safety measures are taken.

If people or objects near the wind turbine generator system (within the distance **R***) could be endangered by pieces of ice thrown off during operation, GE Energy always recommends the use of an ice detector.

The ice detector is installed on the nacelle. It is possible to detect the build-up of a small amount of ice by means of the ice detector. If this is the case, the ice detector sends a signal to the turbine controller.
The turbine controller disconnects the wind turbine generator system from the grid and the rotor is brought to a standstill or rotates at a very low speed. A message about the icy condition is displayed on the monitor in the

turbine, In addition, a message is sent to the service station and the operator via modem. The turbine does not restart until the detector is free of ice or the operator has satisfied himself of the ice-free condition of the rotor blades, has acknowledged the ice alarm message and restarts the plant.

However, ice may form on the rotor blades considerably more quickly than on the ice sensor on the nacelle. As a result, there is a residual risk for the reliable detection of ice build-up on the rotor blades.

The detector on the nacelle must be set relatively sensitively, in order to ensure that the time from when ice starts to build up on the rotor blades until the detector sends a message about the build-up of ice is as short as possible. As a consequence, a certain number of spurious trippings cannot be excluded. Loss of energy yield may occur as a result of the spurious trippings.

If an ice detector is not used, it is advisable to cordon off an area around the wind turbine generator system with the radius **R*** during freezing weather conditions, in order to ensure that individuals are not endangered by pieces of ice thrown off during operation (cf. also section 11.1).

> ***R** = 1.5 x (hub height [m] + rotor diameter [m])
> (Recommendation of the German Wind Energy Institute DEWI 11/1999)

8.4.2 Icy Condition of the Access Route

During the winter months, access to the plants may be very slippery due to ice or hard-packed snow. There is an increased danger of slipping.

cf. section 11.1 on approaching and entering WTGs which may be frosted.

8.4.3 Icy Condition of the Tread of the Steps outside the Nacelle

In the winter months, the tread of the steps outside the nacelle can be icy as a result of ice and hard-packed snow.

8.5 Exceptional Dangers – Earthquakes

In the case of an earthquake, the operator must inspect the WTG for damage. The following procedure is recommended:

- Determination of the acceleration values in the tower top which arose during the earthquake (PCH BOX).
- Contact GE Energy, in order to agree on the further procedure and possible inspection schedules.

9 Safety Information for Individual Plant Components

9.1 Down Tower Assembly

The down tower assembly is the electrical cabinet lineup consisting of:

- Power distribution cabinet (PDC)
- Converter filter cabinet (CFC)
- Converter bridge cabinet (CBC)
- Main control cabinet (MCC)

DANGER

Caution! Danger from electrical current!

All personnel remaining in the WTG must be located between the person carrying out the measurements and the tower entrance during voltage measurements on the low voltage main distribution or on the low voltage main control panel.

Attention! Check the work area / control cabinet before completion of the work!

Remove all loose parts, tools and materials from the control cabinets. Tools and materials left in the control cabinets lead to unsafe working conditions for the service technicians when the plant is put into operation again.

Close and lock the control cabinets before returning to service.

ATTENTION

Please follow respective Lock Out/Tag Out (LOTO) instructions.

9.2 Anemometer and Wind Vane

The anemometer and the wind vane are intensely heated in WTGs with cold weather equipment!

ATTENTION

Hot surface!

Disconnect the anemometer and the wind vane from the supply and allow both to cool down prior to maintenance.

Physical contact may cause burns.

9.3 Top Box

The top box is the electrical cabinet that resides in the nacelle. The main purpose of the top box is to distribute power to the up-tower wind turbine components.

DANGER

Caution! Danger from electrical current!

All personnel remaining in the WTG must be located between the person carrying out the troubleshooting and the nacelle exit during voltage measurements.

Attention! Check the work area / control cabinet before completion of the work!

Remove all loose parts, tools and materials from the cabinet. Tools and materials left in the control cabinets lead to unsafe working conditions for the service technicians when the plant is put into operation again.

Close and lock the control cabinets before returning to service.

ATTENTION

Please follow respective Lock Out/Tag Out (LOTO) instructions.

9.4 Pitch Electrical Control Cabinets Inside the Hub - Axis and Battery

DANGER

Danger from electrical current!

Before beginning any maintenance work, ensure that the control cabinets have been disconnected from all the energy sources in accordance with the currently applicable Lock out/Tag out instructions.

In addition to the main circuits, take any supplementary or auxiliary circuits into account. Wear appropriate electrical PPE for entrance into energized cabinets.

Check the work area/control cabinet before completion of the work!

Remove all loose parts, tools and materials from the cabinet.

Tools and materials left in the control cabinets lead to unsafe working conditions for the service technicians when the plant is put to operation again.

Danger from electrical current!

All axis and battery cabinet doors must be securely latched in place before the system is reenergized to avoid exposure to the potentially hazardous transient voltages that are present during start-up.

10 Conduct in Emergency Situations

10.1 Conduct in Case of Fire

In principle the WTGS consists of fire-resistant materials. However

Fire, open flames and smoking are prohibited!

If a fire does occur, however, **call the fire department immediately!**

State the following information:

- Name of the person calling
- What is on fire
- Where the fire is located (seat of the fire/location of the plant)
  (You will find the site coordinates on the nameplate)
- Wind direction and wind strength

Note the following information in the case of fire:

- Saving lives has priority over fire-fighting
- Alarm all personnel who are in the WTG
- Use the escape routes described in chapter 10.2 – ensure that you are familiar with the various escape routes.
- Do not use the service lift.
- Burning debris can be expected to fall down if there is a fire in the nacelle or the upper part of the tower.
- If the wind turbine generator system is still in operation, it must be stopped and a large area around the plant cordoned off.
- Close the door of the plant.

10.1.1 Fire-Fighting

Fire-fighting may only be carried out by immediately fighting an initial fire using the fire extinguishers that may be available in the plant. The locations of the firefighting equipment (if available) in the tower and the nacelle are marked.

If the initial fire cannot be extinguished within a short time, abandon any further attempts to extinguish the fire and call the fire department immediately.

In addition to the direct danger from the fire, a combustion toxicity hazard and the danger of asphyxia could also arise. As a result, move in a crouched position if smoke develops and also crouch down when attempting to extinguish the fire.

DANGER

Attempts to extinguish a fire may lead to very serious burns!

Do not make any attempts to extinguish the fire beyond the initial attempt. Due to confined space limitations, since the required minimum distance cannot be maintained while attempting to extinguish the fire.

10.1.2 Fire in the Tower - Person in the Nacelle

- Leave the WTG immediately via the second escape route (cf. chapter 10.2).
- Abseiling device in the nacelle - emergency exit using the abseiling device

10.1.3 Fire in the Nacelle - Person in the Nacelle

- Attempt to extinguish the fire.

If unsuccessful:

- Leave the danger area immediately via the first escape route (cf. chapter 10.2).
- Do **not** use the service lift.
- Do **not** use the abseiling device.

10.1.4 Fire in the Transformer

DANGER

Do not make any attempts to extinguish the fire – High voltage! Conventional fire extinguishers are not suitable.

- Leave the WTG immediately.

In the case of transformers in the tower:

- Leave the WTG via the second escape route

In the case of transformers in the transformer station:

- Leave the WTG via the first escape route

Fire-fighting may only be carried out by trained personnel.

10.2 Escape Routes

ATTENTION

Keep escape routes clear!

The escape and rescue routes must be free of obstructions (tools, equipment, rubbish, etc.), in order to ensure that the turbine can be evacuated as quickly as possible in an emergency.

10.2.1 First Escape Route

In case of fire, leave the plant immediately. The first escape route from the nacelle is down the ladder in the tower. The descent is facilitated and made safer by resting platforms every 6 m. Do not use the hoisting passenger suspension device.

10.2.2 Second Escape Route

If the descent through the tower is no longer possible, use the second escape route. (Abseiling with the abseiling device). This either leads over the roof of the nacelle (hooking point on roof rail) or through the emergency descent hatch which may be present (hooking point directly beside the winch in the nacelle, which is also present in this case).

Correct use of the abseiling device:

- Make sure your safety harness if on correctly.
- Attach lanyard to approved tie-off point or nacelle rail.

DANGER

Use of the abseiling device!

Your life could depend on the correct use of the abseiling device.

The abseiling device can also be used by two people to abseil.

Read the instructions before beginning the abseiling operation!

10.3 Information for Rescue and Emergency Personnel

The rescue services and the emergency personnel must be equipped with their own personal protective equipment (safety harness, etc.). The rescue/emergency personnel must bring with them all the equipment required for rescuing personnel from the hub, nacelle or tower.

The information stated in this safety manual must also be read by the rescue / emergency personnel.

10.4 Oil Spill – Immediate Measures

The objective of the immediate measures is to prevent or at least to contain a further uncontrolled escape of water-endangering substances and keep the areas of threatened or contaminated soil as small as possible, under consideration of safety engineering requirements.

NOTE

Inform yourself about the oils used beforehand. The safety data sheets provide details of Water Hazard Classes and suitable measures for combating oil pollution.

Measures

1. Decide and act quickly, so that the amount of oil reaching the environment is kept as small as possible.
2. Prevent further discharge (closure of valves, temporary sealing of cracks and holes, e.g. by means of sealing rags, sealing bags, sealing wedges, collection in containers, pumping out, transfer, etc.)
3. Bind the discharged oil – use approved oil binding agents and oil binder mats if the oil could not be pumped out or skimmed off in time. The damage can be limited by means of collecting containers, rolled foils and a shovel.
4. Prevent the oil from getting into the soil or bodies of water.
5. Remove contaminated soil.
6. Take the contaminated oil-absorbing materials to a local specialist waste disposal company for material recovery/conversion to energy or disposal. The national regulations are to be complied with.

11 Remaining in and on the Wind Turbine Generator System

ATTENTION

Fire Hazard!

The storage of combustible or highly inflammable materials in the wind turbine generator system **is not allowed**.

Personnel may not remain inside the WTG, and maintenance or repair work may not be carried out in or on the WTG under power supply. There is a danger of accident and a danger to life and limb. In order to prevent accidents, the following actions are to be carried out in the following order before and on entering the wind turbine generator system:

1. Shut down the WTG and secure against an unauthorized return to service
2. Put on the personal protective equipment
3. Disable the power supply for the work to be carried out – carry out corresponding Lockout/Tagout instructions (cf. chapter 13)

Staying in the WTGS while it is in operation is unavoidable in the case of certain maintenance and repair work. In such cases a risk assessment should be developed for the task. Particular care is called for and hearing protection must be worn.

In addition, the following safety regulations are to be complied with without fail:

- As a general principle, no person may stay in the WTG during a gale or a thunderstorm! If a thunderstorm comes up, the WTG must be left immediately.
- The WTG may only be entered in the company of a second person who can provide assistance or call for help in the case of an accident.
- The entrance door to the tower must be kept closed or if it is kept open, it must be properly secured to prevent it from flying open and getting warped.
- Long open hair, loose clothing (e.g. flapping coats, tops with wide sleeves or trousers with wide legs) and scarves, ribbons, headscarves or jewelry may not be worn in the WTG! There is a fundamental danger of injury as a result of getting caught, trapped or drawn in by rotating elements! Clothing must always be tailored to suit the respective work and the weather conditions.
- Switch-on and shut-down procedures in accordance with the operating manual are to be complied with for all work which concerns the operation and adjustment of the WTG and its safety equipment.
- If any changes in the operating characteristics which are relevant to safety or any faults arise in the WTG, it must be shut down immediately and the event reported to GE Energy or the customer (if a maintenance contract has not been concluded with GE Energy).

11.1 Approaching and Entering Frosted Wind Turbine Generator Systems

Before parking near the turbine, stop approx. 350 m from the turbine and check the rotor blades for ice by means of binoculars and the sound of the rotation of the blades. If the turbine is running and ice is present on the rotor blades, call for a remote stop.
Once the blades have come to a complete standstill, verify that none of the blades is located over the entrance door of the turbine. If this is the case, call for a remote traverse of the yaw drive in any direction, so that the rotor is positioned on the side of the turbine opposing the door. As soon as the rotor is correctly positioned, call for a remote stop of the yaw drive and ask for confirmation of this operation.

Once the above conditions have been complied with, park your vehicle at a safe distance from the WTGS (at least 100 m). Watch out for falling ice as you approach the tower. If the wind is blowing against the opposite side of the door (or into the rotor at this point), you must proceed with extreme caution, since falling ice could be blown in your direction.

WARNING

Danger of slipping as a result of icy conditions!

There is danger of slipping as a result of the frozen ground and ice on the foundation and the stairs.

Sprinkle de-icing salt or sand over the foundation.

Use the handrail when going up the stairs.

Leave the immediate vicinity of the WTG after completing your work. Watch out for falling ice. Get into your vehicle. Do not call for a remote re-activation of the yaw drive and restart of the turbine until you are approximately 350 m away from the WTG.

11.2 Shut-down of the Wind Turbine Generator System

Before starting any service work, the wind turbine generator system must be deactivated. Proceed as follows:

1. Contact any remote monitoring groups that are supervising the site (before entering the wind turbine)
2. Contact any site operators or maintenance people (before entering the wind turbine)
3. Temporarily disconnect the Mark VIe controller from the site SCADA network:
   — Locate the SCADA network switch in the down tower assembly that houses the SCADA network switch
   — Disconnect the two fiber pairs (RX-TX and RX-TX) from the switch, taking the turbine off the site network
4. Press the "Stop-Reset" button to shut-down the plant manually.
5. Set the key-operated switch to "Repair".

NOTE

Follow lock-out-tag-out procedures to de-energize, lock-out and tag-out equipment to ensure that unit equipment is always put in a safe condition. Wind conditions must be continuously monitored manually if LOTO procedures used mean that the unit is not capable of moving to minimum load condition.

DANGER

Danger of accident!

The WTG must remain shut down as long as personnel are in the plant. Before it is returned to service by authorized personnel, check without fail that nobody is in the plant. Otherwise there is the danger of an accident!

11.3 Climbing the Tower

- Only persons who are physically fit, are wearing appropriate PPE and are capable of coping with the ascent may climb the WTGS.
- The WTGS must be shut down and secured against unauthorized start-up before the tower is ascended. The WTGS must remain shut down as long as anybody is climbing the tower or is on the tower platform.
- In order to avoid accidents caused by falling objects, nobody may stand under the ladder while somebody is ascending the tower. Even a small screwdriver can cause very serious injuries if it drops from a great height.

DANGER

Danger through falling objects!

Falling objects can cause very serious injuries irrespective of their size and weight!

Never stay in the vicinity of the ladder while somebody is ascending or descending. The ladder may only be used by one person at a time. Only after this person has reached an intermediate platform and has closed the tower hatch or has reached the ground in the tower base and stepped back from the ladder may the next person approach the ladder. Tools and equipment must be secured while climbing.

- Fall protection PPE must always be put on correctly before ascending the tower.
- Always check the safety harness and the entire safety equipment prior to use. Damaged PPE may never be used.
- Safety boots and a hardhat must be worn when ascending the tower. Gloves must be worn while climbing.
- The maximum possible fall path must be kept to a minimum by means of rope-shortening devices or similar.

- Only use marked hooking points with an adequate load-bearing capacity.
- The tower may only be ascended by means of the ladder installed inside the tower or (if the person is properly trained) the hoisting passenger suspension devices/service platform which may be installed. (Follow the operating instructions of the manufacturer).
- The rail or cable grab must run freely in the rail while ascending and descending the tower. Never touch the travelling safety hook, otherwise there is a danger of injury!
- Both hands must be kept free during the ascent or descent. Tools, lubricants and other material may only be transported in a suitable bag. Permanent "3-point contact" with the ladder is only guaranteed by this means.
- Greater care needs to be exercised when climbing the ladder experiencing wet conditions or if the tower is covered in ice.
- Only unhook the lanyard after you have reached the tower platform and the access hatch has been closed.
- Ensure that you are always protected by at least one lanyard with a fall arrest block.
- The rest platforms in the tower are fitted with hatches that must be kept closed at all times. The platform hatches must therefore be opened on reaching a platform and closed again immediately after crossing to the next section of the tower. Tie off to anchor points while on platforms when hatches are open.

11.4 Deactivation of the Yaw Drive

Yaw stop switches are located in the tower base, below the nacelle and on the top box in the nacelle. The yaw drive and the automatic nacelle adjustment are disabled in the "Off" switch position, so that the nacelle is technically prevented from moving if there is a change in wind direction.

11.5 Entering the Nacelle

The yaw stop switch on the uppermost tower platform must be placed in the "Off" position before crossing from the tower to the nacelle. The yaw drive and the automatic nacelle adjustment are thereby disabled.

Depending on the position of the nacelle, the available simple ladder is hooked into one of the holders to prevent the ladder from slipping. Some of the WTGs are provided with a permanently installed extension ladder.

Hooking points are available in the vicinity of every platform.

11.6 Walking on the Roof of the Nacelle/Entering the Rotor Hub

The roof of the nacelle may only be accessed for entering the rotor hub and for carrying out work on the wind vane, the anemometer and the obstruction light.

Only trained or instructed staff are permitted to enter the hub or walk on the roof of the nacelle. The rotor lock on the high-speed shaft (brake disk on the coupling) must be engaged before the rotor hub is entered. Reference section 7.2 for specific wind restrictions.

1. **Place the yaw stop switch on the top box in the "Off" position.**
2. **Turn the rotor to the "Y" position, so that the rotor hub can be entered.**
3. **Engage the rotor lock on the high-speed shaft.**
4. **Turn the rotor blades to the 85° feathering position.**

Fig. 15: Rotor in the "Y" position

DANGER

Life-threatening hazard through sudden start-up of the rotor if the rotor lock (brake disk on the coupling) on the high-speed shaft has not been engaged!

Always engage the rotor lock on the high-speed shaft before entering the rotor hub.

FOLLOW THE RESPECTIVE LOCKOUT/TAGOUT INSTRUCTIONS! (cf. section 13).

Falling Hazard! Warning: strong wind currents!

Before climbing out of the nacelle enclosure through the roof hatch above the gearbox, the lanyard must be hooked on to the rail on the nacelle, then transfer to the spinner if transitioning to the hub.

The roof rail is to be selected as a hooking point for all other work on the roof of the nacelle. Follow the hub access and rotor Lock Out/Tag Out (LOTO) procedures, in addition to proper JSA/EHS procedures.

WARNING

Maintenance work inside the hub may only be carried out at maximum wind speeds from 11 - 15 m/s! Reference section 7.2 for specific wind restrictions.

Always engage the rotor lock on the high-speed shaft. Use of the rotor lock on the low-speed shaft only for this purpose is prohibited.

5. **In the hub, place the battery maintenance switch and the pitch maintenance switch on all three axis cabinets in the "Off" position.**

Fig. 16: Battery maintenance switch

6. **Switch the pitch controller on the control cabinet to "Manual".**

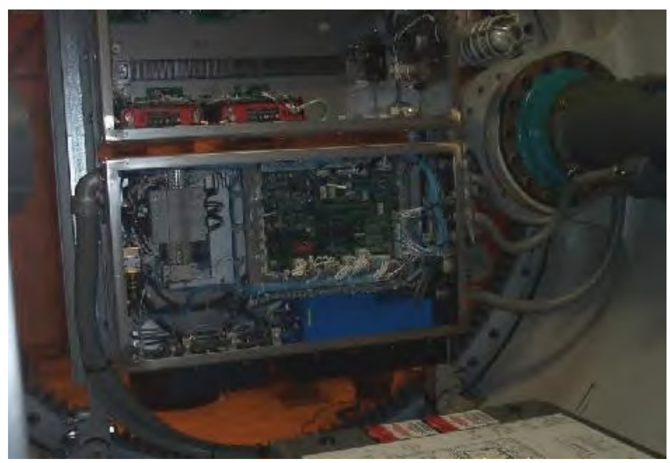


Fig. 17: Pitch controller

Walking on the Roof with Ice and Snow

If you have to walk on the roof of the nacelle or climb into the hub, first of all ensure that the rotor blades are in the Y position before you open the hatch. Otherwise there is danger of injury from falling pieces of ice.

DANGER

Danger of Slipping and Falling Hazard as a result of icy conditions!

There is a high risk of slipping and falling if the roof of the nacelle and the spinner are covered by snow and ice.

Completely remove any snow and ice from the roof before walking on it. Sprinkle sand on the cleared areas

Do not walk on the roof/spinner if the snow and ice cannot be removed completely and the danger of slipping cannot be excluded. Proper JSA/EHS procedures should be followed at all times.

11.7 Activation of the Wind Turbine Generator System

DANGER

Danger of accident!

The WTG must remain shut down as long as personnel are in the turbine. Before it is returned to service by authorized personnel, check without fail that nobody is in the turbine. Otherwise the danger of an accident arises!

Proceed as follows to return the WTG to service:

1. Make an entry in the service life card of the WTG.
2. Connect the Mark VIe controller to the site SCADA network:
   - Locate the SCADA network switch in the down tower assembly that houses the SCADA network switch
   - Reconnect the two fiber pairs (RX-TX and RX-TX) from the switch, putting the turbine on the site network
3. Set the key-operated switch to "Operation".
4. Check the alarm message panel in home web page for error messages
5. Press the "Stop-Reset" button and then the "Start" button.
6. Inform the remote monitoring division that wind turbine is back in operation.
7. Inform the operator / customer that wind turbine is back in operation.

12 Information on Maintenance and Troubleshooting

Only trained or instructed staff may be deployed!

Trainee personnel or personnel undergoing orientation or general training may only carry out work on the wind turbine generator system under the constant supervision of an experienced person.

Personnel must familiarize themselves with the work environment around the wind turbine generator system before starting work!

As it is possible to start the plant by means of the remote monitoring system, the WTG must be shut down for maintenance work as described in Chapter 11.2. In addition, the service switch on the control cabinet must be placed in the "Maintenance" or "Repair" position. Once the maintenance or repair work has been completed, the service switch must be returned to the "Automatic" position.

Maintenance/inspection of the cable winch in the tower is the responsibility of the operator and must be carried out in accordance with the operating and maintenance instructions of the supplier of the cable winch.

Time limits for recurring tests/inspections prescribed or stated in the operating manual must be adhered to.

Suitable workshop equipment is essential for carrying out maintenance measures.

Work on electric equipment of the WTGS may only be carried out by a skilled electrician, equipment specific trained technician or by instructed persons under the guidance and supervision of a skilled electrician in accordance with the electrical engineering regulations.

Any safety equipment which has to be dismantled to carry out maintenance and repair work must be re-installed and checked immediately after the maintenance and repair work has been completed!

The wind turbine generator system, in particular the connections and bolted connections, must be cleaned of any oil, consumables and process materials, dirt or old preservative agents at the beginning of any maintenance/ repair / conservation work.

Only entrust experienced persons with the fastening of loads.

Individual components and larger modules which need to be exchanged must be carefully attached and secured to lifting gear, in order to minimize the danger that emanates from them. Only use suitable lifting gear and load suspension devices which are in a technically perfect condition and have an adequate load bearing capacity!

Follow the operating instructions of the winch manufacturer.

Never stand or work below suspended loads.

Use the specified or other safe ascent equipment and working platforms to carry out installation work above head height. Wear fall protection equipment when carrying out maintenance work at great heights. Keep all handles, steps, safety rails, platforms, stages and ladders free of dirt.

Ensure that consumables and process materials and replacement parts are disposed of safely and in an environmentally-friendly manner!

13 Power Disconnection and Isolation Procedures (Lock-out/Tag-out Instructions)

Pursuant to EN 50308 and OSHA standard 29 CFR 1910.147, wind turbine generator systems must be equipped with devices to disconnect and isolate them from all their energy sources during inspection and maintenance work.

These disconnecting/energy-isolating devices are prescribed for all mechanical, electrical and hydraulic energy sources.

GE Energy advises the plant operator/owner to develop specific procedures for the power disconnection and isolation of every individual subsystem.

Local and national regulations must be taken into account when developing workplace-specific Lockout/Tagout instructions.

The disconnection/isolation points are marked in the plant-specific circuit diagrams and hydraulic schematics supplied with the respective WTG.

Procedures for the Lock-out/Tag-out of power disconnection and isolation devices must consider the following aspects:

13.1 Identification of Installations, Processes, Circuits

(Individual mechanical, electrical or hydraulic subsystems)

13.2 Preparation for Shutdown / Notification of Affected Employees

- All personnel who may be affected must be notified before Lock-out/Tag-out devices are installed and after they have been removed. In addition to this procedure, authorized employees must be aware of any additional safety requirements prescribed for working on this type of equipment.
- Affected employees who work on or near an installation which is about to be disconnected and on which Lock-out/Tag-out devices are to be mounted must be notified thereof.

13.3 Identification of Energy Sources and Strengths

13.4 Deactivation of Energy Sources and the Mounting of Energy Control Devices

- The power disconnection and isolation devices (e.g. disconnecting switches or load interrupter switches, valves etc.) must be positioned in such a way that they interrupt the energy flow to installations, processes or circuits. The authorized employees are obliged to mount and secure Lock-out/Tag-out devices to these. They must hereby ensure that the power disconnection and isolation devices are "locked out" until further notice and remain in their safety or "Off" position.

13.5 Control of Stored Energy

ATTENTION

Residual risks from stored energy!

PLEASE OBSERVE THE RESPECTIVE LOCKOUT / TAGOUT INSTRUCTIONS!

- The authorized employee must ensure that all potentially hazardous energy in any form (stored, residual, chemical or potential energy) is relieved, dissipated, contained, discharged or otherwise controlled. Additional measures may be necessary to prevent the re-accumulation or re-storage of energy, in order to protect personnel. Stored energy can form e.g. in batteries, capacitors, through gravity or in chemical lines.

13.6 Verification of Isolation

- The authorized employee must verify that the isolation and de-energization of the respective installation, process or circuit has actually been carried out before maintenance work may be started. The check must confirm that the installation, process or circuit has achieved a "zero" energy state. (Test equipment, circuit activation attempts, measuring devices, visual inspections, etc. can be used to verify the zero energy state.)

13.7 Reconnection of the Installation to the Supply

The authorized employee must carry out the following measures before returning the installation to service:

- Inspection of the work area to ensure that all items which are not required for the operation of the installation have been removed and that all the guards have been replaced, that the machine/installation, process or circuit is operational and that all personnel are in a safe location.
- Removal of all locks, tags and other Lock-out/Tag-out devices from all power disconnection and isolation devices by the authorized employee who previously attached these LOTO devices.
- Notification of affected personnel that the energy supply is about to be restored to the machine/installation, process or circuit.
- Visual inspection and/or cycle test to verify that the service or maintenance work has been successfully completed. Provided that the work has been completed, the machine/installation, process or circuit may be returned to service. Otherwise, the requisite procedural steps must be repeated.
- Correct sequential run-up of the installation, process or circuit.

WTG operators must ensure that suitable disconnection regulations are available for their plants and construction sites and those they are implemented. GE Energy has developed installation-specific Lock-out/Tag-out procedures for the activities listed below. This list does not claim to be complete, however. It may be advisable to develop additional procedures as a result of changes to installations or to comply with construction site-specific disconnection regulations.

Service Jobs / Subsystems	Installations, Processes, Circuits
Gear box / gearing lubricant	Nacelle – protection of the gear lubricant flow
Work in the converter cabinet / on the generator	Isolation of converter cabinet from dangerous energy / isolation of generator from dangerous energy
Surge protector / medium voltage	De-energize power distribution cabinet (PDC) at MV transformer.
Surge protector / high voltage	De-energize power distribution cabinet (PDC) at MV transformer.
Work on the synchronization switch	Isolation of the synchronization switch. De-energize power distribution cabinet (PDC) at MV transformer.
Work on the safety isolated WTG	Disconnection of the power distribution cabinet.
Disconnection of the 400 V power supply	Disconnection of the 400 V power supply to the power distribution cabinet in the tower base and to the top control cabinet in the nacelle and to the hub.
Disconnection of the 690 V power supply	Disconnection of the 690 V power supply to the power distribution cabinet in the tower base and to the top control cabinet in the nacelle.
Work on the transformer in the DTA converter filter cabinet	Disconnection of the transformer in the DTA converter filter cabinet
Work on the UPS voltage output	Disconnection of the 230 V UPS voltage output in the main cabinet and the control cabinet, the nacelle and the hub
Disconnection of the 24 V power supply unit in the main cabinet	Disconnection of the 24 V power supply unit in the main cabinet
Isolation of the 400 V power supply from the nacelle to the hub	Isolation of the 400 V power supply from the nacelle (top control cabinet) to the hub
Nacelle hydraulics	24 V transformer / interruption of the hydraulic supply
24 V transformer in the nacelle	24 V transformer in the top control cabinet (e.g. for exchanging the transformer)
Battery charging voltage nacelle / hub	Disconnection of the battery charging voltage to the hub
230 V power supply to the nacelle	Disconnection of the battery charger, interruption of the 230 V power supply
Nacelle / motors	Disconnection of the motor
400 V motor circuit breaker in the nacelle	Disconnection of the 400 V motor circuit breaker
Work in the hub	Disconnection of the motor (hub)
Work in the hub	Back-up battery pack in the hub
Locking the high-speed shaft	Nacelle / high-speed shaft (gear box)
Locking the low-speed shaft	Nacelle / low-speed shaft (gear box)
Work on the transformer	Isolation of the transformer in WTGS with a transformer in the tower

ANNEX: Items and Installations which are subject to Inspection pursuant to the Accident Prevention Regulations

Article to be tested	Test before the initial operation	Exceptional tests	Regular tests	Proof of test	Regulations
Winches	To be checked by a technically competent person		Regular check by a technically competent person in accordance with the manufacturer's instructions and operational conditions.	Inspect and test log book and inspection sticker	Manufacturer's instructions
Doors Emergency exits	To be checked by a technically competent person. Doors must be executed so that they are self-closing, open in the direction of escape and can be easily opened from the inside at all times without auxiliary means.		Regular check by the operator. Once a year by a technically competent person.	Documentary evidence	Manufacturer's instructions
Escape routes			In case of danger, the work areas must be able to evacuated via escape routes or escape equipment. It must be ensured that at least one escape route can also be used in the case of a power failure. Escape routes or escape equipment are: routes via ladders and abseiling devices.		
Service lift	To be checked by an expert. In addition to the experts of the Technical Inspection Association (TÜV), only experts for the inspection of hoisting passenger suspension devices who are authorized by the trade association are considered to be experts for the purposes of this safety regulation. The operator must ensure that a test run is carried out at the installation location in all directions of movement with the working load of the passenger suspension device in the presence of the supervisor before the initial operation.	The operator must ensure that hoisting passenger suspension devices are subjected to an exceptional test by a qualified person after cases of damage or particular events which could affect the carrying capacity, as well as after any repair work.	All components of the hoisting passenger suspension device must be inspected for operational safety by a technically competent person at least once a year. Shorter test intervals may arise as a result of the service conditions. The manufacturer's instructions are to be followed.	Documentary evidence	Manufacturer's instructions
Fire extinguishers (optional feature)			Regular check by a technically competent person or expert in accordance with the national regulations.	Inspection sticker or test report	

Article to be tested	Test before the initial operation	Exceptional tests	Regular tests	Proof of test	Regulations
Personal protective equipment against falling (safety harness)	Check of the fall protection rail by an experienced person.		Users must check the PPE for its orderly condition and correct function before it is used. An experienced person must check the PPE for perfect condition at regular intervals. The manufacturer's instructions are to be followed.	Inspect and test log book, inspection sticker	Manufacturer's instructions
Abseiling device	To be checked by an experienced person.	To be checked by an experienced person after use.	Users must check the abseiling device for its orderly condition and correct function before it is used. An experienced person must check the abseiling device for perfect condition at regular intervals. The manufacturer's instructions are to be followed.	Inspect and test log book, inspection sticker	Manufacturer's instructions
Ladder		A technically competent person checks the orderly condition of mechanical ladders after any alterations or repairs.	A technically competent person checks the orderly condition of the ladders and steps once a year. Irrespective of this, the user must check the suitability and condition of the ladders before use. The manufacturer's instructions are to be followed.	Inspect and test log book, inspection sticker	Manufacturer's instructions
Electrical equipment	Check by a qualified electrician or under the supervision of a qualified electrician. (Also after alteration or repair) The test before the initial operation in accordance with Section 1 is not necessary if the manufacturer or installer confirms that the electrical installations and equipment are designed to comply with the provisions of this accident prevention regulation.		At specified intervals: The intervals are to be calculated in such a way that any defects which can be expected to arise are found in due time. The relevant electro-technical regulations are to be complied with for the check. At the request of the trade association, an inspection and test log book with specified entries is to be kept. The manufacturer's instructions are to be followed.	Inspect and test log book	Manufacturer's instructions
First aid box (optional feature)	Pursuant to the Law on Medical Devices, which has been in force since 1st January 1995*, bandaging materials must have a CE-marking but do not have to have a use-by date. If a use-by date is stated, however, the Law on Medical Devices prohibits further use after expiry of the use-by date under penalty of a fine. First aid material without a use-by date must only be replaced in the event of soiling or damage. With the exception of plaster material, it remains usable over a long period, provided that it is stored in a clean and dry place.				

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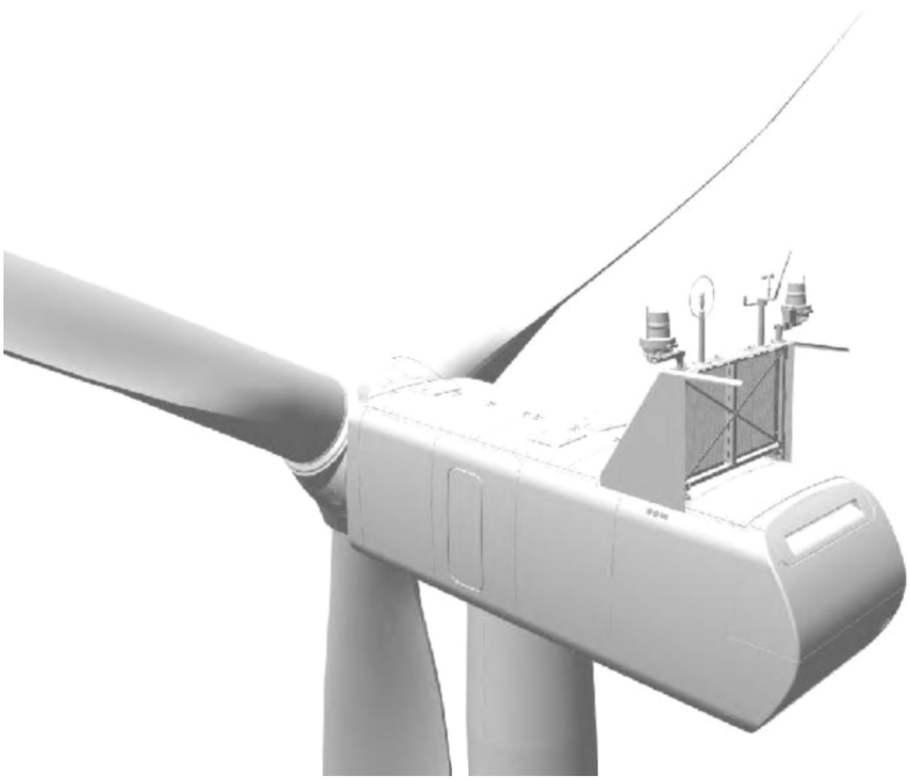
General specification

2.0/2.2MW V110/100 50/60Hz



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See general reservations, notes, and disclaimers to this general specification in section General reservations, notes, and disclaimers, p. 21.

1 Abbreviations and technical terms

Abbreviation	Explanation
AEP	Annual Energy Production
EMC	Electromagnetic Compatibility
HH	Hub Height
HV	High Voltage
LPS	Lightning Protection System
MASL	Meters Above Sea Level
MW	Megawatt
OH&S	Occupational Health & Safety
OVRT	Over Voltage Ride-Through
pu	Per unit
rpm	Revolutions per minute
SSR-P	Sub Synchronous Resonance Protection
UVRT	Under Voltage Ride-Through

Table 1-1: Abbreviations

Term	Explanation
None	

Table 1-2: Explanation of terms

2 General description

The Vestas 2.0MW series wind turbine is a pitch-regulated upwind turbine with active yaw, gearbox and a three-blade rotor. The turbine is available in two rotor diameters 100 or 110m with a generator rated at 2.0 or 2.2MW. The turbine utilises a microprocessor pitch control system called OptiTip® and the OptiSpeed™ (variable speed) feature. With these features, the wind turbine is able to operate the rotor at variable speed (rpm), helping to maintain output at or near rated power.

Rotor	Rating [MW]	Wind Class [IEC]	Hub Height [m]	
			50Hz	60Hz
V100	2.0	IIB	80, 95	80, 95
		IIC	80	80
	2.2	S	80, 95	80, 95
V110	2.0	IIIA	95	80, 95
	2.0	IIIB	95, 110, 120, 125	95, 110
	2.0	IIIC	80	80
	2.2	S	80, 95 110, 120, 125	80, 95

Table 2-1: Turbine variants and tower heights

3 Safety

The safety specifications in this safety section provide limited general information about the safety features of the turbine and are not a substitute for Buyer and Buyer's agents taking all appropriate safety precautions, including but not limited to (a) complying with all applicable safety, operation, maintenance, and service agreements, instructions, and requirements, (b) complying with all safety-related laws, regulations, and ordinances, (c) conducting all appropriate safety training and education and (d) reading and understanding all safety-related manuals and instructions. See section 3.11 Manuals and warnings for additional guidance.

3.1 Access

Access to the turbine from the outside is through the bottom of the tower. The door is equipped with a lock. Access to the top platform in the tower is by a ladder or service lift. Access to the nacelle from the top platform is by ladder. Access to the transformer room in the nacelle is controlled with a lock. Unauthorised access to electrical switchboards and power panels in the turbine is prohibited according to IEC 60204-1 2006.

3.2 Escape

In addition to the normal access routes, alternative escape routes from the nacelle are through the crane hatch.

The hatch in the roof can be opened from both the inside and the outside.

Escape from the service lift is by ladder.

3.3 Rooms/working areas

The tower and nacelle are equipped with connection points for electrical tools for service and maintenance of the turbine.

3.4 Climbing facilities

A ladder with a fall arrest system (rigid rail or wire system) is installed through the tower.

There are anchor points in the tower, nacelle, hub, and on the roof for attaching a full-body harness (fall arrest equipment).

Over the crane hatch there is an anchor point for the emergency descent equipment.

3.5 Moving parts, guards, and blocking devices

Moving parts in the nacelle are shielded.

The turbine is equipped with a rotor lock to block the rotor and drive train.

It is possible to block the pitch of the cylinder with mechanical tools in the hub.

3.6 Lighting

The turbine is equipped with light in tower, nacelle, and hub.

There is emergency light in case of the loss of electrical power.

3.7 Emergency stop buttons

There are emergency stop buttons in the nacelle and in the bottom of the tower.

3.8 Power disconnection

The turbine is designed to allow for disconnection from all its power sources during inspection or maintenance. The switches are marked with signs and are located in the nacelle and in the bottom of the tower.

3.9 Fire protection/first aid

A CO_2 (recommended) or ABC fire extinguisher and first aid kit must be available in the nacelle during all service and maintenance activities. A fire blanket must be available nearby for all those activities for which the respective work instruction requires it.

3.10 Warning signs

Additional warning signs inside or on the turbine must be reviewed before operating or servicing the turbine.

3.11 Manuals and warnings

The Vestas Corporate OH&S Manual and manuals for operation, maintenance, and service of the turbine provide additional safety rules and information for operating, servicing, or maintaining the turbine.

4 Type approvals

The turbine will be type-certified according to the certification standards listed below:

- IEC 61400-22

5 Operational envelope and performance guidelines

Actual climate and site conditions have many variables and must be considered in evaluating actual turbine performance. The design and operating parameters set forth in this section do not constitute warranties, guarantees, or representations as to turbine performance at actual sites.

The turbine can be equipped with different power generation components depending on the region which may influence the performance of the turbine. Consult Vestas Wind Systems for further details.

NOTE As evaluation of climate and site conditions is complex, it is necessary to consult Vestas for every project.

5.1 Climate and site conditions

Values refer to hub height and as determined by the sensors and control system of the turbine.

Extreme design parameters				
Wind climate	**V100**		**V110**	
	2MW	**2.2MW**	**2MW**	**2.2MW**
	IEC IIB	**IEC S**	**IEC IIIA**	**IEC S**
Ambient temperature range (standard turbine)	-30° to +50°C	-30° to +50°C	-30° to +50°C	-30° to +50°C
Ambient temperature interval (low temperature turbine)	-40° to +50°C	-40° to +50°C	-40° to +50°C	-40° to +50°C
Extreme wind speed (10-minute average)	42.5 m/s	42.5 m/s	37,5 m/s	37,5 m/s
Survival wind speed (3-second gust)	59.5 m/s	59.5 m/s	52,5 m/s	52,5 m/s

Table 5-1: Extreme design parameters

Average design parameters				
Wind climate	**V100**		**V110**	
	2MW	**2.2MW**	**2MW**	**2.2MW**
	IEC IIB	**IEC S**	**IECA**	**IEC S**
Annual average wind speed	8.5 m/s	7,5 m/s	7,5 m/s	6,5 m/s
Form factor, c	2.0	2,2	2,0	2,0
Turbulence intensity according to IEC 61400-1:2005, including wind farm turbulence (@15 m/s – 90% quartile)	16%	16%	18%	18%
Wind shear	0.20	0.20	0.20	0.20
Inflow angle (vertical)	8°	8°	8°	8°

Table 5-2: Average design parameters

5.1.1 Complex terrain

Classification of complex terrain according to IEC 61400-1:2005 Chapter 11.2.

For sites classified as complex, appropriate measures are to be included in the site assessment.

5.1.2 Altitude

The turbine is designed for use at altitudes up to 1500 metres above sea level as standard.

With altitudes above 1500 metres, special considerations must be taken regarding for example HV installations and cooling performance. Consult Vestas for further information.

5.1.3 Wind farm layout

Turbine spacing is to be evaluated site-specifically. Spacing below three rotor diameters (2D) may require sector-wise curtailment.

5.2 Operational envelope (temperature and wind)

Values refer to hub height and are determined by the sensors and control system of the turbine.

Operational envelope (temperature and wind)				
Wind climate	**V100**		**V110**	
	2MW	**2.2MW**	**2MW**	**2.2MW**
	IEC IIB	**IEC S**	**IECA**	**IEC S**
Ambient temperature interval (standard temperature turbine)	-20° to +40°C	-20° to +40°C[1]	-20° to +40°C	-20° to +40°C[1]
Ambient temperature interval (low temperature turbine)[1]	-30° to +40°C	-30° to +40°C[1]	-30° to +40°C	-30° to +40°C[1]
Cut-in (10 minute average)	3 m/s	3 m/s	3 m/s	3 m/s
Cut-out (10 minute average)	22 m/s	22 m/s	20 m/s	20 m/s
Re-cut in (10 minute average)	20 m/s	20 m/s	18 m/s	18 m/s

Table 5-3: Operational envelope (temperature and wind)

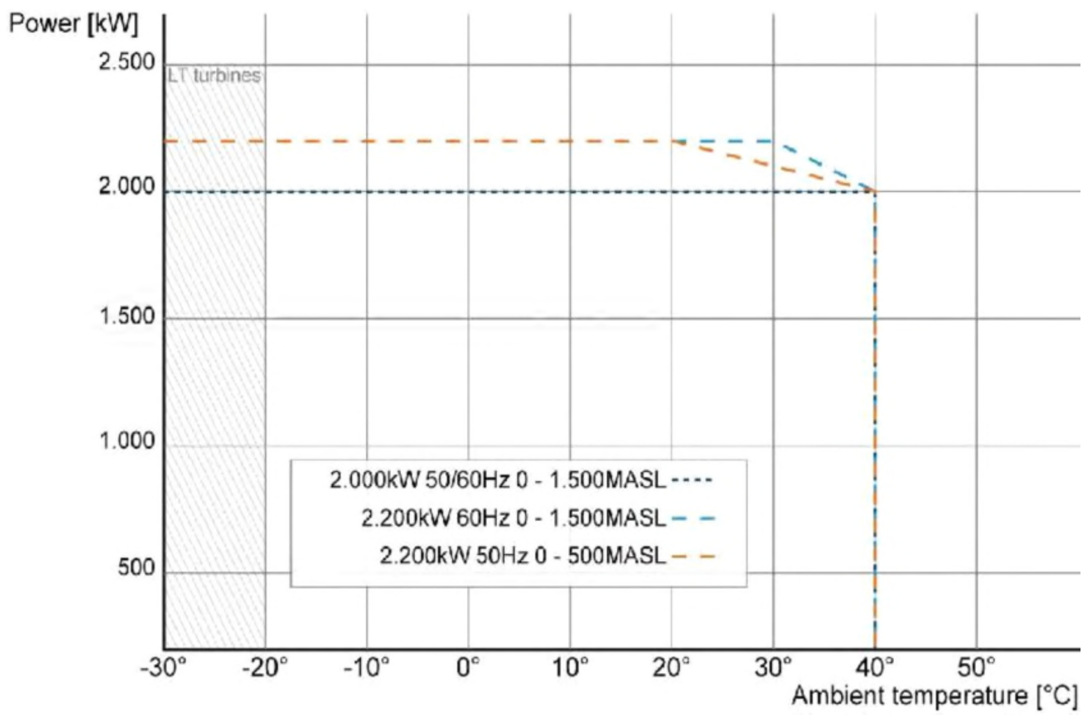

Figure 5-1: Temperature and de-rate curves

[1] Limitation in high temperature performance will apply for IEC S turbines

5.3 Operational envelope (grid connection)

Operational envelope (grid connection)		
Nominal phase voltage	$[U_{NP}]$	400 V
Nominal frequency	$[f_N]$	50 / 60Hz
Maximum frequency gradient	±4 Hz/sec.	
Maximum negative sequence voltage	3% (connection) 2% (operation)	
Minimum required short circuit ratio at turbine HV connection	5%	
Maximum short circuit current contribution	1.45 pu (peak)	

Table 5-4: Operational envelope (grid connection)

Generator and converter disconnecting values		
	50Hz	**60Hz**
Frequency is above [Hz] for 0.2 Seconds	53 Hz	63,6Hz
Frequency is below [Hz] for 0.2 Seconds	47 Hz	56,4Hz

Table 5-5: Generator and converter disconnecting values

NOTE Over the turbine lifetime, grid drop-outs are to occur at an average of no more than 50 times a year.

5.4 Reactive power capability

The turbine has a reactive power capability dependent on power rating as illustrated in Figure 5-2 and Figure 5-3.

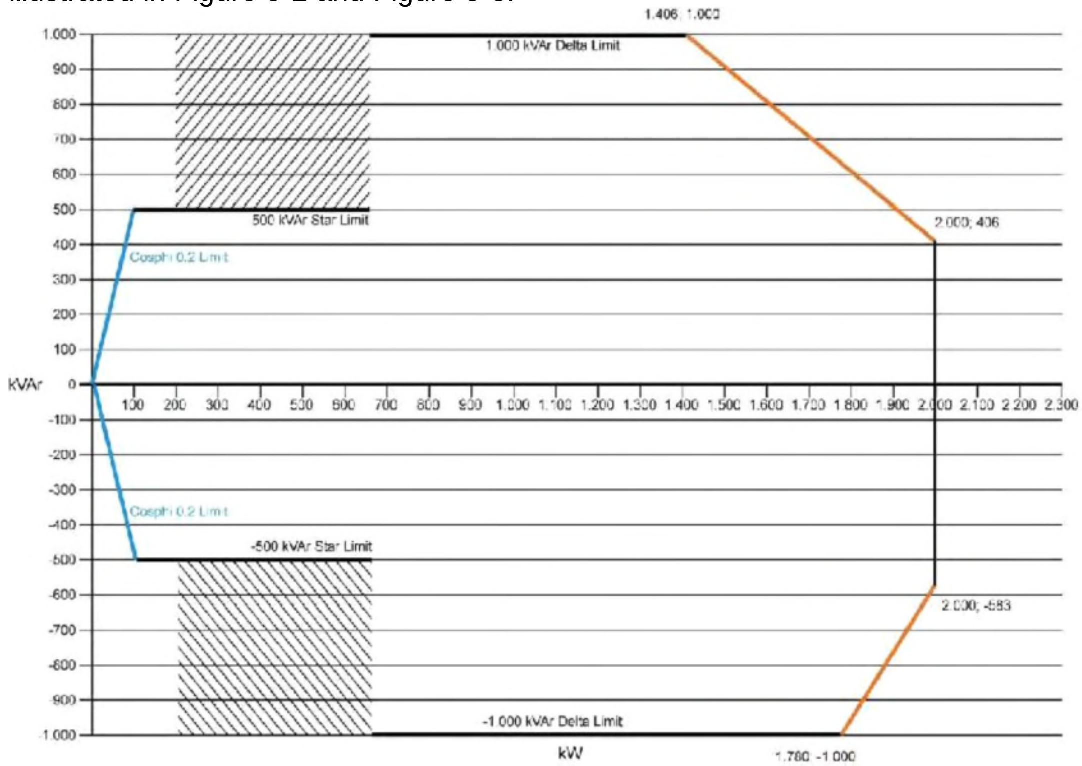

Figure 5-2: Reactive power capability for 2.0MW variants 50 and 60Hz

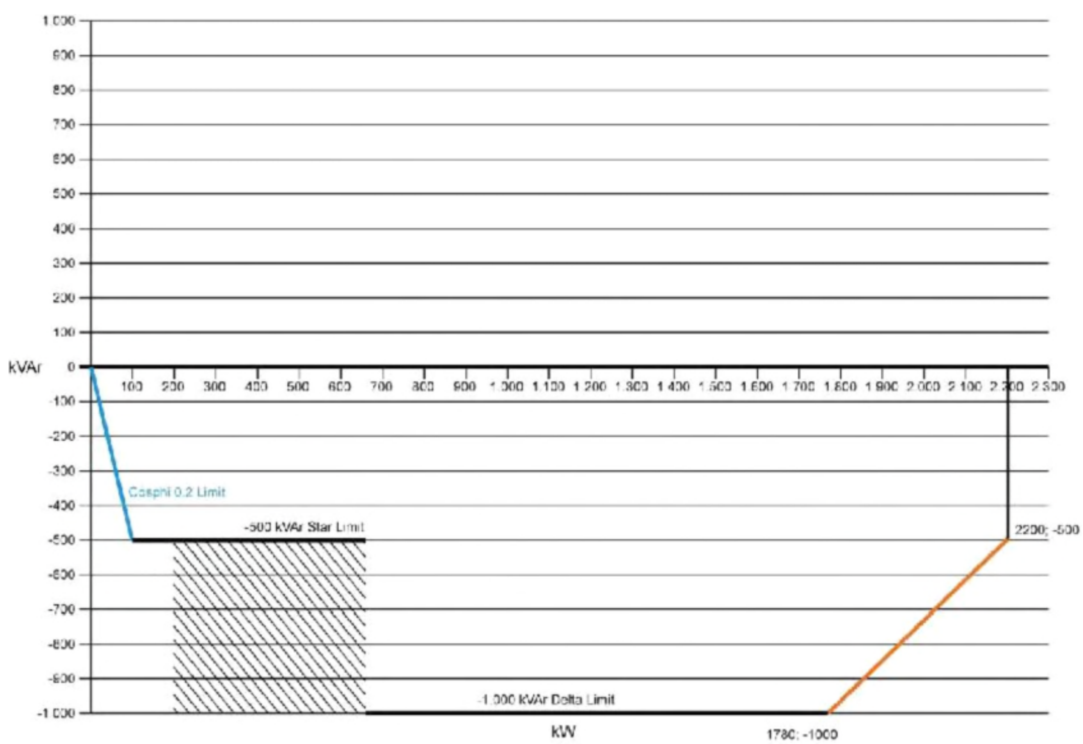

Figure 5-3: Reactive power capability for 2.2MW variants 50 and 60Hz

The above chart applies to the low-voltage side of the HV transformer. The turbine maximises active power or reactive power depending on grid voltage conditions.

5.5 Fault ride through

5.5.1 UVRT

The turbine is equipped with a reinforced converter system in order to gain better control of the generator during grid faults. The turbine control system continues to run during grid faults.

The pitch system is optimised to keep the turbine within normal speed conditions, and the generator speed is accelerated in order to store rotational energy and be able to resume normal power production faster after a fault and keep mechanical stress on the turbine at a minimum.

The turbine is designed to stay connected during grid disturbances within the UVRT curve in Figure 5-4, p. 12.

Power recovery time	
Power recovery to 90% of pre-fault level	Maximum 2 seconds

Table 5-6: Power recovery time

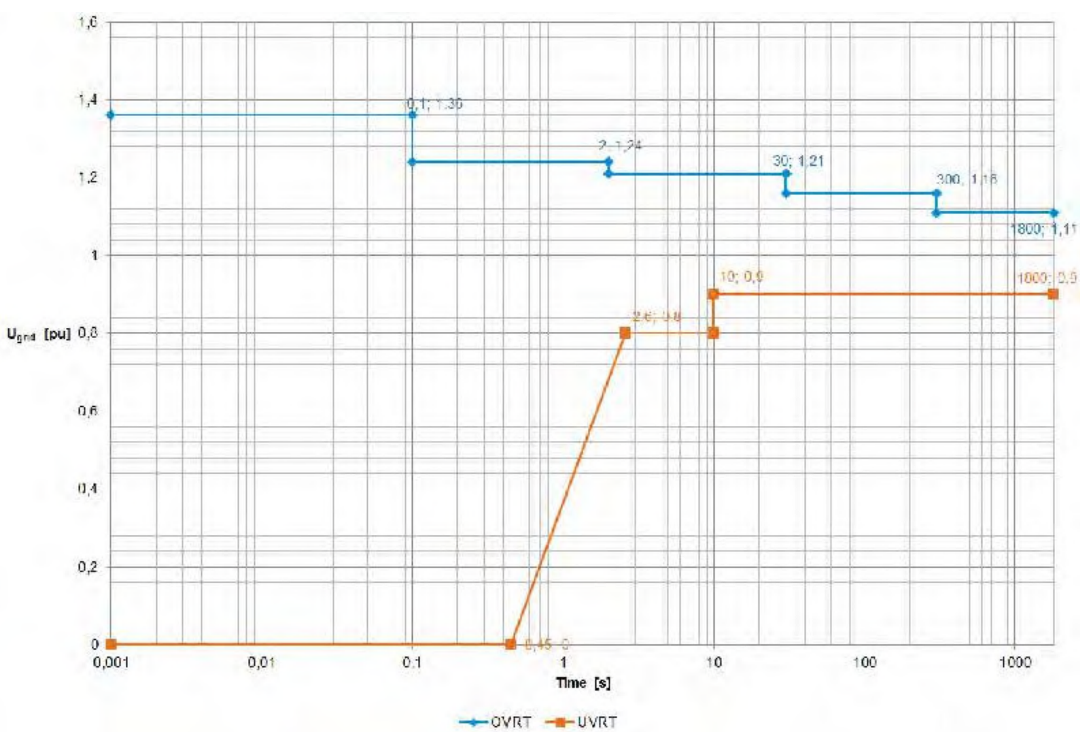

Figure 5-4: OVRT, UVRT curves for symmetrical and asymmetrical faults where U_{grid} represents grid voltage values

The turbine stays connected when the values are above UVRT (and protection) and below OVRT.

5.5.2 OVRT

The turbine is able to run with voltage levels above nominal within restricted time intervals.

The generator and the converter will be disconnected if the voltage level exceeds the OVRT curve shown in Figure 5-4.

5.5.3 Reactive current contribution

The reactive current contribution depends on whether the fault applied to the turbine is symmetrical or asymmetrical.

Symmetrical reactive current contribution

During symmetrical voltage dips the wind farm will inject reactive current to support the grid voltage. The reactive current injected is a function of the voltage measured at the low voltage side of the WTG transformer.

The default value gives a reactive current part of 1 p.u. of the nominal WTG current. Figure 5-5 indicates the reactive current contribution as a function of the voltage. The reactive current contribution is independent from the actual wind conditions and pre-fault power level.

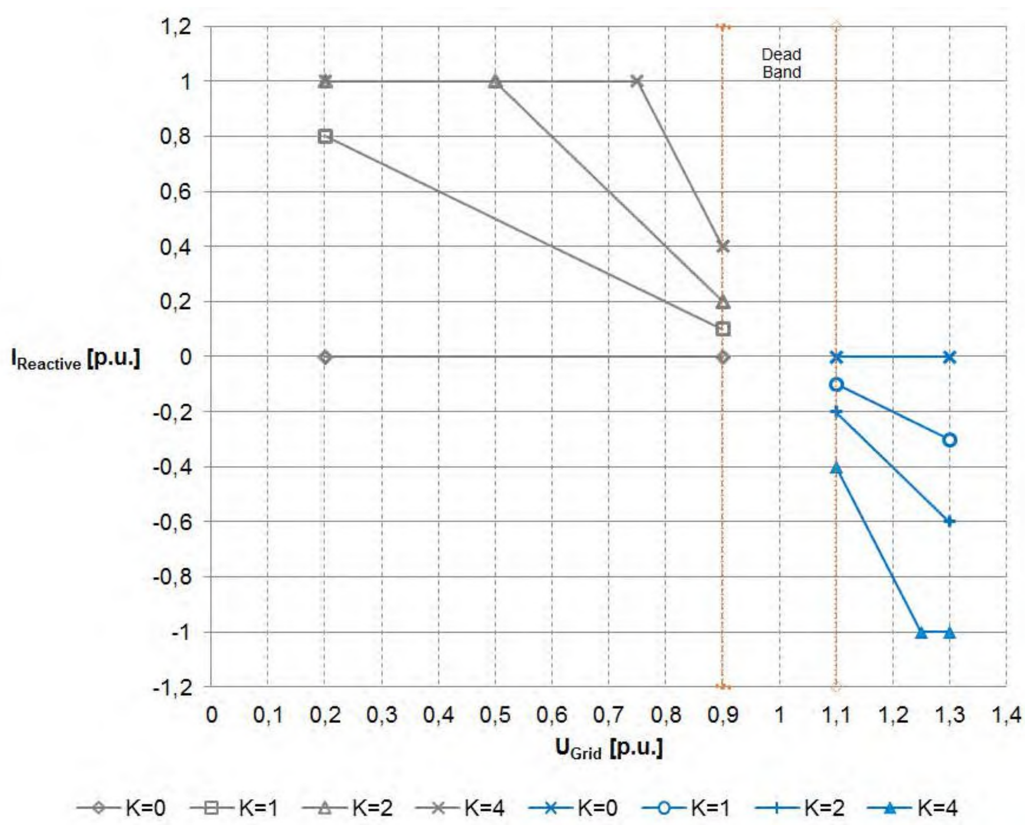

Figure 5-5: Reactive current contribution

Slope (K-factor), offset and dead band can be set freely to fulfil requirements to UVRT current injection.

Asymmetrical reactive current contribution

Current reference values are controlled during asymmetrical faults to ensure ride through.

5.5.4 Sub synchronous resonance protection

Turbine is equipped with fast-acting protection to shield the converter, generator and drivetrain from excessive voltages, currents and torques due to sub-synchronous resonance (SSR) caused by interaction between the turbine and the series-capacitor-compensated transmission lines. The generator and converter will be disconnected upon SSR detection by the turbine controller, according to Table 5-7: SSR protection time. SSR protections availability is depending on grid conditions at the specific sites.

SSR protection time	
Generator and converter disconnect	Maximum 100ms (including breaker response time)

Table 5-7: SSR protection time

5.6 Active and reactive power control

The turbine is designed for control of active and reactive power by means of the VestasOnline® SCADA system.

Maximum ramp rates for external control	
Active power[2]	0.1 pu/sec
Reactive power[2]	2.5 pu/sec

Table 5-8: Maximum ramp rates for external control data

To protect the turbine, active power cannot be controlled to values below the curve in Figure 5-6, p. 15.

[2] Limitations in duration of a power ramp may apply.

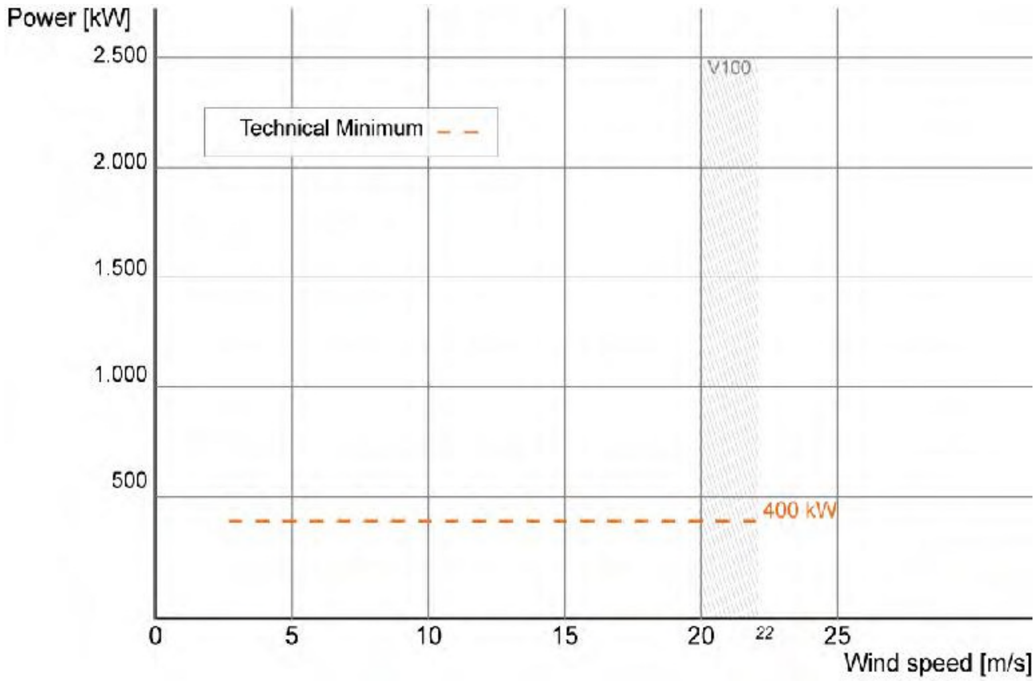

Figure 5-6: Minimum active power output related to wind speed

5.7 Voltage control

The turbine is designed for integration with VestasOnline® voltage control by utilising the turbine reactive power capability.

5.8 Frequency control

The turbine can be configured to perform frequency control by decreasing the output power as a linear function of the grid frequency (over frequency).

Dead band and slope for the frequency control function are configurable.

5.9 High voltage connection

5.9.1 Transformer

The step-up HV transformer is located in a separate locked room in the back of the nacelle.

The transformer is a three-phase, two-winding, dry-type transformer that is self-extinguishing. The windings are delta-connected on the high-voltage side unless otherwise specified.

The transformer comes in different versions depending on the market where it is intended to be installed.

- The transformer is as default designed according to IEC standards for both 50 Hz and 60Hz versions.
- For turbines installed in Member States of the European Union, it is required to fulfil the Ecodesign regulation No 548/2014 set by the European Commission.

5.9.2 HV Switchgear (Option)

As an option Vestas can deliver a gas insulated switchgear which is installed in the bottom of the tower as an integrated part of the turbine. Its controls are integrated with the turbine safety system which monitors the condition of the switchgear and high voltage safety related devices in the turbine. This ensures all protection devices are fully operational whenever high voltage components in the turbine are energised. The earthing switch of the circuit breaker contains a trapped-key interlock system with its counterpart installed on the access door to the transformer room in order to avoid unauthorized access to the transformer room during live condition.

The switchgear is available in two variants with increasing features – see *Table 5-9 - HV switchgear variants and features*. Beside the increase in features, the switchgear can be configured depending on the number of grid cables planned to enter the individual turbine. The design of the switchgear solution is optimized such grid cables can be connected to the switchgear even before the tower is installed and still maintain its protection toward weather conditions and internal condensation due to a gas tight packing.

The switchgear is available in an IEC version and in an IEEE version. The IEEE version is however only available in the highest voltage class.

HV Switchgear		
Variant	**Basic**	**Streamline**
IEC standards	○	⦿
IEEE standards	⦿	○
Vacuum circuit breaker panel	⦿	⦿
Overcurrent, short-circuit and earth fault protection	⦿	⦿
Disconnector / earthing switch in circuit breaker panel	⦿	⦿
Voltage Presence Indicator System for circuit breaker	⦿	⦿
Voltage Presence Indicator System for grid cables	⦿	⦿
Double grid cable connection	⦿	⦿
Triple grid cable connection	⦿	○
Preconfigured relay settings	⦿	⦿
Turbine safety system integration	⦿	⦿
Redundant trip coil circuits	⦿	⦿
Trip coil supervision	⦿	⦿
Pendant remote control from outside of tower (Option via ground controller)	⦿	⦿
Sequential energisation	⦿	⦿
Reclose blocking function	⦿	⦿
Heating elements	⦿	⦿
Trapped-key interlock system for circuit breaker panel	⦿	⦿
UPS power back-up for protection circuits	⦿	⦿
Motor operation of circuit breaker	⦿	⦿
Cable panel for grid cables (configurable)	○	⦿
Switch disconnector panels for grid cables – max three panels (configurable)	○	⦿
Earthing switch for grid cables	○	⦿
Internal arc classification	○	⦿
Supervision on MCB’s	○	⦿

Table 5-9 - HV switchgear variants and features

5.10 Main contributors to own consumption

The consumption of electrical power by the wind turbine is defined as consumption when the wind turbine is not producing energy (generator is not connected to the grid). This is defined in the control system as Production Generator (zero).

The following components have the largest influence on the power consumption of the wind turbine:

Main contributors to own consumption	
Hydraulic motor	20 kW
Yaw motors 6 x 1.75 kW	10.5 kW
Oil heating 3 x 0.76 kW	2.3 kW
Air heaters (2 x 6 kW)	12 kW
Oil pump for gearbox lubrication	5.0 kW
Generator fans (included in generator efficiency)	7.0 kW
Average of measured no-load loss of the HV transformer	4.0 kW

Table 5-10: Own consumption data

6 Drawings

6.1 Structural design – illustration of outer dimensions

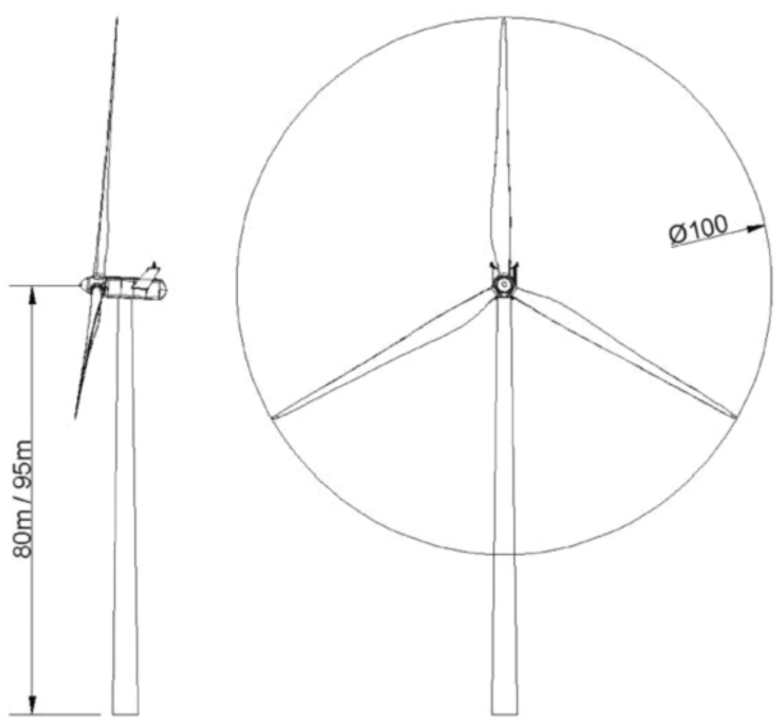

Figure 6-1: Illustration of outer dimensions for a V100 turbine

6.2 Structural design (side-view drawing)

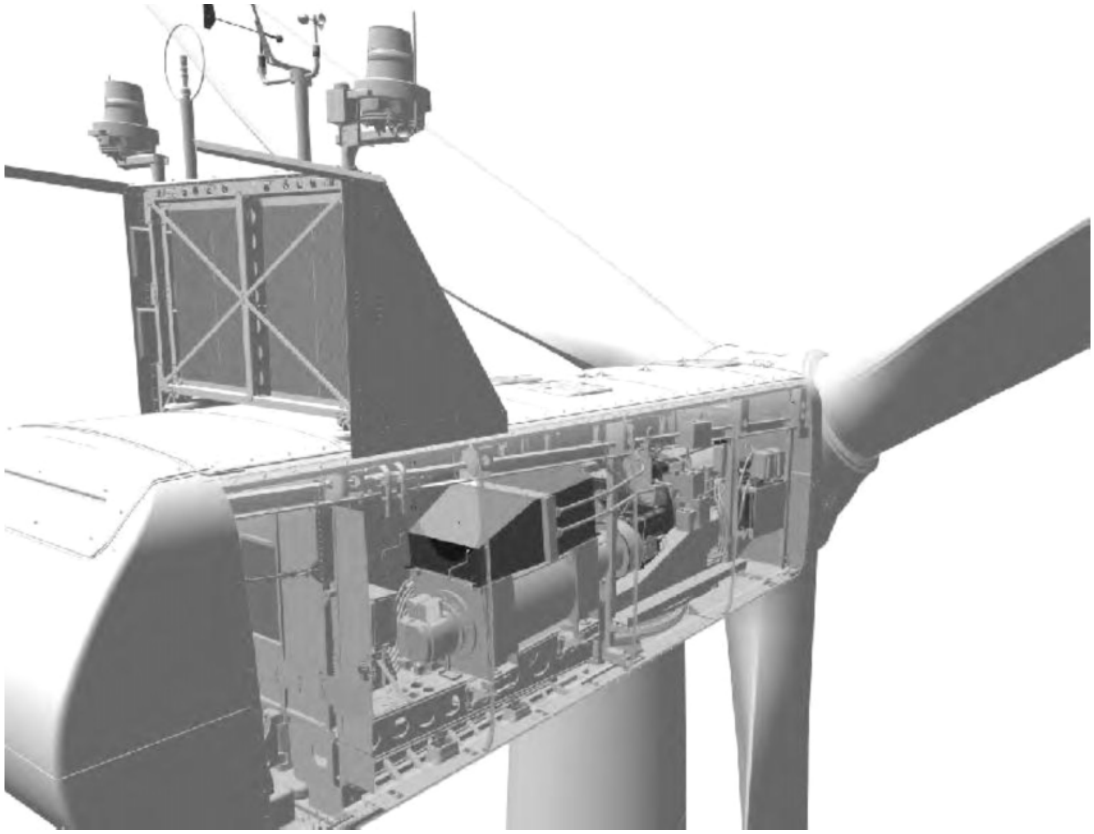

Figure 6-2: Side-view drawing

6.3 Turbine protection systems

6.3.1 Braking concept

The main brake on the turbine is aerodynamic. Braking the turbine is done by feathering the three blades. During emergency stop all three blades will feather simultaneously to full end stop, thereby slowing the rotor speed.

In addition there is a mechanical disc brake on the high-speed shaft of the gearbox. The mechanical brake is only used as a parking brake and when activating the emergency stop push buttons.

6.4 Overspeed protection

The generator rpm and the main shaft rpm are registered by inductive sensors and calculated by the wind turbine controller to protect against overspeed and rotating errors.

In addition, the turbine is equipped with a safety PLC, an independent computer module that measures the rotor rpm. In case of an overspeed situation, the safety PLC activates the emergency feathered position (full feathering) of the three blades independently of the turbine controller.

6.5 EMC system

The turbine and related equipment must fulfil the EU EMC-directive with later amendments:

- European Parliament Council directive 2004/108/EC of 15 December 2004 on the approximation of the laws of the Member States relating to electromagnetic compatibility.
- The EMC-directive with later amendments.

6.6 Lightning protection system

The LPS consists of three main parts.

- Lightning receptors.
- Down conducting system.
- Earthing system.

NOTE The LPS is designed according to IEC standards.

6.7 Earthing

The Vestas Earthing System is based on foundation earthing.

Document 0000-3388 ‘Vestas Earthing System’ contains the list of documents pertaining to the Vestas Earthing System.

Requirements in the Vestas Earthing System specifications and work descriptions are minimum requirements from Vestas and IEC. Local and national requirements may require additional measures.

7 Environment

7.1 Chemicals

Chemicals used in the turbine are evaluated according to the Vestas Wind Systems A/S Environmental System certified according to ISO 14001:2004.

- Anti-freeze liquid to help prevent the cooling system from freezing.
- Gear oil for lubricating the gearbox.
- Hydraulic oil to pitch the blades and operate the brake.
- Grease to lubricate bearings.
- Various cleaning agents and chemicals for maintenance of the turbine.

8 General reservations, notes, and disclaimers

-
- The general specification document here described applies to the present design of the 2.0MW wind turbine series. Updated versions of the wind turbine, which may be manufactured in the future, may have a general specification document that differs from these general specifications. In the event that Vestas supplies an updated version of the wind turbine, Vestas will provide updated general specification applicable to the updated version.
- Vestas recommends that the grid be as close to nominal as possible with little variation in frequency.
- A certain time allowance for turbine warm-up must be expected following grid dropout and/or periods of very low ambient temperature.
- The estimated power curve for the different estimated noise levels (sound power levels) is for wind speeds at 10 minute average value at hub height and perpendicular to the rotor plane.
- All listed start/stop parameters (for example wind speeds and temperatures) are equipped with hysteresis control. This can, in certain borderline situations, result in turbine stops even though the ambient conditions are within the listed operation parameters.
- The earthing system must comply with the minimum requirements from Vestas, and be in accordance with local and national requirements, and codes of standards.
- This document, 'General Specifications', is not an offer for sale, and does not contain any guarantee, warranty, and/or verification of the power curve and noise (including, without limitation, the power curve and noise verification method). Any guarantee, warranty, and/or verification of the power curve and noise (including, without limitation, the power curve and noise verification method) must be agreed to separately in writing.

9 Appendices

9.1 Design codes – structural design

The structural design has been developed and tested with regard to, but not limited to, the following main standards:

Design codes – structural design	
Nacelle and hub	IEC 61400-1:2005 EN 50308 ANSI/ASSE Z359.1-2007
Bed frame	IEC 61400-1:2005
Tower	IEC 61400-1:2005 Eurocode 3

Table 9-1: Structural design codes

9.2 Design codes – mechanical equipment

The mechanical equipment has been developed and tested with regard to, but not limited to, the following main standards:

Design codes – mechanical equipment	
Gear	Designed in accordance with rules in ISO 81400-4
Blades	DNV-OS-J102 IEC 1024-1 IEC 60721-2-4 IEC 61400 (Part 1, 12, 22 and 23) DEFU R25 ISO 2813 DS/EN ISO 12944-2

Table 9-2: Mechanical equipment design codes

9.3 Design codes – electrical equipment

The electrical equipment has been developed and tested with regard to, but not limited to, the following main standards:

Design codes – electrical equipment	
High-voltage AC circuit breakers	IEC 60056
High-voltage testing techniques	IEC 60060
Power capacitors	IEC 60831
Insulating bushings for AC voltage above 1 kV	IEC 60137
Insulation coordination	BS EN 60071

Design codes – electrical equipment	
AC disconnectors and earth switches	BS EN 60129
Current transformers	IEC 60185
Voltage transformers	IEC 60186
High-voltage switches	IEC 60265
Disconnectors and fuses	IEC 60269
Flame retardant standard for MV cables	IEC 60332
Transformer	IEC 60076-11
Generator	IEC 60034
Specification for sulphur hexafluoride for electrical equipment	IEC 60376
Rotating electrical machines	IEC 34
Dimensions and output ratings for rotating electrical machines	IEC 72 and IEC 72A
Classification of insulation, materials for electrical machinery	IEC 85
Safety of machinery – electrical equipment of machines	IEC 60204-1

Table 9-3: Electrical equipment design codes

9.4 Design codes – I/O network system

The distributed I/O network system has been developed and tested with regard to, but not limited to, the following main standards:

Design codes – I/O network system	
Salt mist test	IEC 60068-2-52
Damp head, cyclic	IEC 60068-2-30
Vibration sinus	IEC 60068-2-6
Cold	IEC 60068-2-1
Enclosure	IEC 60529
Damp head, steady state	IEC 60068-2-56
Vibration random	IEC 60068-2-64
Dry heat	IEC 60068-2-2
Temperature shock	IEC 60068-2-14
Free fall	IEC 60068-2-32

Table 9-4: I/O network system design codes

9.5 Design codes – EMC system

To fulfil EMC requirements the design must be as recommended for lightning protection. See section 9.6 Design codes – lightning , p. 24.

Design codes – EMC system	
Designed according to	IEC 61400-1: 2005
Further robustness requirements according to	TPS 901795

Table 9-5: EMC system design codes

9.6 Design codes – lightning protection

The LPS is designed according to lightning protection level I:

Design codes – lightning protection	
Designed according to	IEC 62305-1: 2006 IEC 62305-3: 2006 IEC 62305-4: 2006
Non-harmonized standard and technically normative documents	IEC/TR 61400-24:2010

Table 9-6: Lightning protection design codes

9.7 Design codes – earthing

The Vestas Earthing System design is based on and complies with the following international standards and guidelines:

- IEC 62305-1 Ed. 1.0: Protection against lightning – Part 1: General principles.
- IEC 62305-3 Ed. 1.0: Protection against lightning – Part 3: Physical damage to structures and life hazard.
- IEC 62305-4 Ed. 1.0: Protection against lightning – Part 4: Electrical and electronic systems within structures.
- IEC/TR 61400-24. First edition. 2002-07. Wind turbine generator systems – Part 24: Lightning protection.
- IEC 60364-5-54. Second edition 2002-06. Electrical installations of buildings – Part 5-54: Selection and erection of electrical equipment – Earthing arrangements, protective conductors and protective bonding conductors.

9.8 Operational envelope conditions for power curve (at hub height)

Conditions for power curve (at hub height)	
Wind shear	0.00-0.30 (10 minute average)
Turbulence intensity	6-12% (10 minute average)
Blades	Clean
Rain	No
Ice/snow on blades	No
Leading edge	No damage
Terrain	IEC 61400-12-1
Inflow angle (vertical)	0 ±2°

Table 9-7: Conditions for power curve

9.9 Power curves, C_t values, and sound power levels

Power curve, C_t values and sound power levels for noise modes are defined in separate performance specifications for each variant. The documents will reference this General Specification to ensure correct traceability between performance data sheet and the General Specification.

The turbine can be equipped with different power generation components depending on the region which may influence the performance of the turbine. Consult Vestas Wind Systems for further details.

The Performance Specifications are listed below:

Performance specifications	Number
V100-2.2MW 50/60Hz	0051-0204
V110-2.2MW 50/60Hz	0051-0205
V100-2.0MW 50/60Hz	0051-0207
V110-2.0MW 50/60Hz	0051-0208

Table 9-8: Performance specifications

Restricted
Document no.: 0053-3707 V01
2015-11-24

General Description
3MW Platform

Vestas Wind Systems A/S · Hedeager 42 · 8200 Aarhus N · Denmark · www.vestas.com

Table of contents

Recipient acknowledges that (i) this General Description is provided for recipient's information only, and, does not create or constitute a warranty, guarantee, promise, commitment, or other representation (Commitment) by Vestas Wind Systems or any of its affiliated or subsidiary companies (Vestas), all of which are disclaimed by Vestas and (ii) any and all Commitments by Vestas to recipient as to this general description (or any of the contents herein) are to be contained exclusively in signed written contracts between recipient and Vestas, and not within this document.

See general reservations, notes and disclaimers (including, section 12, p. 37) to this general description.

1 Introduction

The 3MW Platform wind turbine configurations covered by this General Description are listed below.

Turbine	Configuration
V105	V105-3.45 MW IEC IA 50/60 Hz
	V105-3.60 MW IEC IA 50/60 Hz Power Mode
V112	V112-3.45 MW IEC IA 50/60 Hz
	V112-3.60 MW IEC IA 50/60 Hz Power Mode
V117	V117-3.45 MW IEC IB 50/60 Hz
	V117-3.60 MW IEC S 50/60 Hz Power Mode
	V117-3.45 MW IEC IIA 50/60 Hz
	V117-3.60 MW IEC IIA 50/60 Hz Power Mode
V126	V126-3.45 MW IEC IIB 50/60 Hz – Low Torque
	V126-3.45 MW IEC IIIA 50/60 Hz – Low Torque
	V126-3.45 MW IEC IIA 50/60 Hz – High Torque
	V126-3.60 MW IEC IIA 50/60 Hz Power Mode – High Torque
	V126-3.45 MW IEC IIIA 50/60 Hz – High Torque
	V126-3.60 MW IEC IIIA 50/60 Hz Power Mode – High Torque
V136	V136-3.45 MW IEC IIIA 50/60 Hz

Table 1-1: 3MW Platform turbine configurations covered

2 General Description

Vestas 3MW Platform comprises a family of wind turbines sharing a common design basis. The 3MW Platform family of wind turbines includes V105-3.45 MW, V112-3.45 MW, V117-3.45 MW, V126-3.45 MW and V136-3.45 MW. These turbines are pitch regulated upwind turbines with active yaw and a three-blade rotor. The wind turbine family provides rotors with a diameter in the range 105 m to 136 m and a rated output power of 3.45 MW. A 3.6 MW Power Mode (PM) is available for all variants except V136-3.45 MW.

The wind turbine family utilises the OptiTip® concept and a power system based on an induction generator and full-scale converter. With these features, the wind turbine is able to operate the rotor at variable speed and thereby maintain the power output at or near rated power even in high wind speed. At low wind speed, the OptiTip® concept and the power system work together to maximise the power output by operating at the optimal rotor speed and pitch angle.

Operating the wind turbine with 3.6 MW Power Mode is achieved by extended derate strategy and reduced reactive power capability compared with 3.45 MW operation.

3 Mechanical Design

3.1 Rotor

The wind turbine is equipped with a rotor consisting of three blades and a hub. The blades are controlled by the microprocessor pitch control system OptiTip®. Based on the prevailing wind conditions, the blades are continuously positioned to optimise the pitch angle.

Rotor	V105	V112	V117	V126	V136
Diameter	105 m	112 m	117 m	126 m	136 m
Swept Area	8659 m^2	9852 m^2	10751 m^2	12469 m^2	14527 m^2
Speed, Dynamic Operation Range	8.3-17.6	8.1-17.6	6.7-17.6	5.6(7.0)-16.5	5.6-15.3
Rotational Direction	Clockwise (front view)				
Orientation	Upwind				
Tilt	6°				
Hub Coning	4°				
Number of Blades	3				
Aerodynamic Brakes	Full feathering				

Table 3-1: Rotor data

3.2 Blades

The blades are made of carbon and fibreglass and consist of two airfoil shells bonded to a supporting beam.

Blades	V105	V112	V117	V126	V136
Type Description	Airfoil shells bonded to supporting beam			Infused structural airfoil shell	
Blade Length	51.15 m	54.65 m	57.15 m	61.66 m	66.66 m
Material	Fibreglass reinforced epoxy, carbon fibres and Solid Metal Tip (SMT)				
Blade Connection	Steel roots inserted				
Airfoils	High-lift profile				
Maximum Chord	4.0 m				4.2 m

Table 3-2: Blades data

3.3 Blade Bearing

The blade bearings are double-row four-point contact ball bearings.

Blade Bearing	
Lubrication	Grease

Table 3-3: Blade bearing data

3.4 Pitch System

The turbine is equipped with a pitch system for each blade and a distributor block, all located in the hub. Each pitch system is connected to the distributor block with flexible hoses. The distributor block is connected to the pipes of the hydraulic rotating transfer unit in the hub by means of three hoses (pressure line, return line and drain line).

Each pitch system consists of a hydraulic cylinder mounted to the hub and a piston rod mounted to the blade bearing via a torque arm shaft. Valves facilitating operation of the pitch cylinder are installed on a pitch block bolted directly onto the cylinder.

Pitch System	
Type	Hydraulic
Number	1 per blade
Range	-10° to 90°

Table 3-4: Pitch system data

Hydraulic System	
Main Pump	Two redundant internal-gear oil pumps
Pressure	260 bar
Filtration	3 µm (absolute)

Table 3-5: Hydraulic system data.

3.5 Hub

The hub supports the three blades and transfers the reaction loads to the main bearing and the torque to the gearbox. The hub structure also supports blade bearings and pitch cylinders.

Hub	
Type	Cast ball shell hub
Material	Cast iron

Table 3-6: Hub data

3.6 Main Shaft

The main shaft transfers the reaction forces to the main bearing and the torque to the gearbox.

Main Shaft	
Type Description	Hollow shaft
Material	Cast iron

Table 3-7: Main shaft data

3.7 Main Bearing Housing

The main bearing housing covers the main bearing and is the first connection point for the drive train system to the bedplate.

Main Bearing Housing	
Material	Cast iron

Table 3-8: Main bearing housing data

3.8 Main Bearing

The main bearing carries all thrust loads.

Main Bearing	
Type	Double-row spherical roller bearing
Lubrication	Automatic grease lubrication

Table 3-9: Main bearing data

3.9 Gearbox

The main gear converts the low-speed rotation of the rotor to high-speed generator rotation.

The disc brake is mounted on the high-speed shaft. The gearbox lubrication system is a pressure-fed system.

Gearbox	
Type	Planetary stages + one helical stage
Gear House Material	Cast
Lubrication System	Pressure oil lubrication
Backup Lubrication System	Oil sump filled from external gravity tank
Total Gear Oil Volume	1000-1200
Oil Cleanliness Codes	ISO 4406-/15/12
Shaft Seals	Labyrinth

Table 3-10: Gearbox data

3.10 Generator Bearings

The bearings are grease lubricated and grease is supplied continuously from an automatic lubrication unit.

3.11 High-Speed Shaft Coupling

The coupling transmits the torque of the gearbox high-speed output shaft to the generator input shaft.

The coupling consists of two 4-link laminate packages and a fibreglass intermediate tube with two metal flanges. The coupling is fitted to two-armed hubs on the brake disc and the generator hub.

3.12 Yaw System

The yaw system is an active system based on a robust pre-tensioned plain yaw-bearing concept with PETP as friction material.

The yaw gears have a torque limiter.

Yaw System	
Type	Plain bearing system
Material	Forged yaw ring heat-treated. Plain bearings PETP
Yawing Speed (50 Hz)	0.45°/sec.
Yawing Speed (60 Hz)	0.55°/sec.

Table 3-11: Yaw system data

Yaw Gear	
Type	Multiple stages geared
Ratio Total	944:1
Rotational Speed at Full Load	1.4 rpm at output shaft

Table 3-12: Yaw gear data

3.13 Crane

The nacelle houses the internal safe working load (SWL) service crane. The crane is a single system hoist.

Crane	
Lifting Capacity	Maximum 800 kg

Table 3-13: Crane data

3.14 Towers

Tubular towers with flange connections, certified according to relevant type approvals, are available in different standard heights. The towers are designed with the majority of internal welded connections replaced by magnet supports to create a predominantly smooth-walled tower. Magnets provide load support in a horizontal direction and internals, such as platforms, ladders, and such like, are supported vertically (that is, in the gravitational direction) by a mechanical connection. The smooth tower design reduces the required steel thickness, rendering the tower lighter compared to one with all internals welded to the tower shells.

Available hub heights are listed in the Performance Specification for each turbine variant. Designated hub heights include a distance from the foundation section to the ground level of approximately 0.2 m depending on the thickness of the bottom flange and a distance from tower top flange to centre of the hub of 2.2 m.

Towers	
Type	Cylindrical/conical tubular

Table 3-14: Tower structure data

3.15 Nacelle Bedplate and Cover

The nacelle cover is made of fibreglass. Hatches are positioned in the floor for lowering or hoisting equipment to the nacelle and evacuation of personnel. The roof section is equipped with wind sensors and skylights. The skylights can be opened from both inside the nacelle to access the roof and from outside to access the nacelle. Access from the tower to the nacelle is through the yaw system.

The nacelle bedplate is in two parts and consists of a cast iron front part and a girder structure rear part. The front of the nacelle bedplate is the foundation for the drive train and transmits forces from the rotor to the tower through the yaw system. The bottom surface is machined and connected to the yaw bearing and the yaw gears are bolted to the front nacelle bedplate.

The crane girders are attached to the top structure. The lower beams of the girder structure are connected at the rear end. The rear part of the bedplate serves as the foundation for controller panels, the cooling system and transformer. The nacelle cover is installed on the nacelle bedplate.

Type Description	**Material**
Nacelle Cover	GRP
Bedplate Front	Cast iron
Bedplate Rear	Girder structure

Table 3-15: Nacelle bedplate and cover data

3.16 Thermal Conditioning System

The thermal conditioning system consists of a few robust components:

- The Vestas CoolerTop® located on top of the rear end of the nacelle. The CoolerTop® is a free flow cooler, thus ensuring that there are no electrical components in the thermal conditioning system located outside the nacelle.
- The Liquid Cooling System, which serves the gearbox, hydraulic systems, generator and converter is driven by an electrical pumping system.
- The transformer forced air cooling comprised of an electrical fan.

3.16.1 Generator and Converter Cooling

The generator and converter cooling systems operate in parallel. A dynamic flow valve mounted in the generator cooling circuit divides the cooling liquid flow. The cooling liquid removes heat from the generator and converter unit using a free-air flow radiator placed on the top of the nacelle. In addition to the generator, converter unit and radiator, the circulation system includes an electrical pump and a three-way thermostatic valve.

3.16.2 Gearbox and Hydraulic Cooling

The gearbox and hydraulic cooling systems are coupled in parallel. A dynamic flow valve mounted in the gearbox cooling circuit divides the cooling flow. The cooling liquid removes heat from the gearbox and the hydraulic power unit through heat exchangers and a free-air flow radiator placed on the top of the nacelle. In addition to the heat exchangers and the radiator, the circulation system includes an electrical pump and a three-way thermostatic valve.

3.16.3 Transformer Cooling

The transformer is equipped with forced-air cooling. The ventilator system consists of a central fan, located below the converter and an air duct leading the air to locations beneath and between the high voltage and low voltage windings of the transformer.

3.16.4 Nacelle Cooling

Hot air generated by mechanical and electrical equipment is removed from the nacelle by a fan system located in the nacelle.

3.16.5 Optional Air Intake Hatches

Primary air intakes in the nacelle can optional be fitted with hatches which can be operated as a part of the thermal control strategy. In case of lost grid to the turbine, the hatches will automatically be closed.

4 Electrical Design

4.1 Generator

The generator is a three-phase asynchronous induction generator with cage rotor that is connected to the grid through a full-scale converter.

The generator housing allows the circulation of cooling air within the stator and rotor. The air-to-water heat exchange occurs in an external heat exchanger

Generator	
Type	Asynchronous with cage rotor
Rated Power [P_N]	3650 kW / 3800 kW
Frequency [f_N]	0-100 Hz
Voltage, Stator [U_{NS}]	3 x 750 V (at rated speed)
Number of Poles	4/6

Winding Type	Form with VPI (Vacuum Pressurized Impregnation)
Winding Connection	Star or Delta
Rated rpm	1450-1550 rpm
Overspeed Limit Acc. to IEC (2 minutes)	2400 rpm
Generator Bearing	Hybrid/ceramic
Temperature Sensors, Stator	3 PT100 sensors placed at hot spots and 3 as back-up
Temperature Sensors, Bearings	1 per bearing
Insulation Class	F or H
Enclosure	IP54

Table 4-1: Generator data

4.2 Converter

The converter is a full-scale converter system controlling both the generator and the power quality delivered to the grid.

The converter consists of 3 machine-side converter units and 3 line-side converter units operating in parallel with a common controller.

The converter controls conversion of variable frequency power from the generator into fixed frequency AC power with desired active and reactive power levels (and other grid connection parameters) suitable for the grid. The converter is located in the nacelle and has a grid side voltage rating of 650 V. The generator side voltage rating is up to 750 V dependent on generator speed.

Converter	
Rated Apparent Power [S_N]	4000 kVA
Rated Grid Voltage	650 V
Rated Generator Voltage	750 V
Rated generator Current	3550 A
Enclosure	IP54

Table 4-2: Converter data

4.3 HV Transformer

The step-up HV transformer is located in a separate locked room in the back of the nacelle.

The transformer is a three-phase, two-winding, dry-type transformer that is self-extinguishing. The windings are delta-connected on the high-voltage side unless otherwise specified.

The transformer comes in different versions depending on the market where it is intended to be installed.

- For 50 Hz regions the transformer is as default designed according to IEC standards. However on special request, a 60 Hz transformer based on IEC standards could also be delivered. Refer to Table 3-3.
- For turbines installed in Member States of the European Union, it is required to fulfil the Ecodesign regulation No 548/2014 set by the European Commission. Refer to Table 3-4.
- For 60 Hz regions the transformer is as default designed mainly according to IEEE standards but on areas not covered by IEEE standards, the design is also based on parts of the IEC standards. Refer to Table 3-5.

4.3.1 IEC 50 Hz/60 Hz version

Transformer	
Type description	Dry-type cast resin transformer.
Basic layout	3 phase, 2 winding transformer.
Applied standards	IEC 60076-11, IEC 60076-16, IEC 61936-1.
Cooling method	AF
Rated power	4000 kVA
Rated voltage, turbine side	
U_m 1.1kV	0.650 kV
Rated voltage, grid side	
U_m 12.0kV	10.0-11.0 kV
U_m 24.0kV	11.1-22.0 kV
U_m 36.0kV	22.1-33.0 kV
U_m 41.5kV	33.1-36.0 kV
Insulation level AC / LI / LIC	
U_m 1.1kV	3[1] / - / - kV
U_m 12.0kV	28[1] / 75 / 75 kV
U_m 24.0kV	50[1] / 125 / 125 kV
U_m 36.0kV	70[1] / 170 / 170 kV
U_m 41.5kV	80[1] / 170 / 170 kV
Off-circuit tap changer	±2 x 2.5 %
Frequency	50 Hz / 60Hz
Vector group	Dyn5 / YNyn0
No-load loss [2]	>5.8 kW
Load loss @ rated power HV, 120°C [2]	>30.5 kW
No-load reactive power [2]	>16 kVAr
Full load reactive power [2]	>345 kVAr
No-load current [2]	0.5 %
Positive sequence short-circuit impedance @ rated power, 120°C [3]	9.0 %
Positive sequence short-circuit resistance@ rated power, 120°C [2]	0.8 %
Zero sequence short-circuit impedance@ rated power, 120°C [2]	8.2 %
Zero sequence short-circuit resistance@ rated power, 120°C [2]	0.7 %
Inrush peak current [2]	
Dyn5	6-9 x $\hat{I}_n$
YNyn0	8-12 x $\hat{I}_n$

Transformer	
Half crest time [2]	~0.7 s
Sound power level	≤ 80 dB(A)
Average temperature rise at max altitude	≤90 K
Max altitude [4]	2000 m
Insulation class	155 (F)
Environmental class	E2
Climatic class	C2
Fire behaviour class	F1
Corrosion class	C4
Weight	≤9500 kg
Temperature monitoring	PT100 sensors in LV windings and core
Overvoltage protection	Surge arresters on HV terminals
Temporary earthing	3 x Ø20 mm earthing ball points

Table 4-3: Transformer data for IEC 50 Hz/60 Hz version

NOTE

[1] @1000m. According to IEC 60076-11, AC test voltage is altitude dependent. All values are preliminary.
[2] Based on an average of calculated values across voltages and manufacturers. All values are preliminary.
[3] Subjected to standard IEC tolerances. All values are preliminary.
[4] Transformer max altitude may be adjusted to match turbine location.

4.3.2 Ecodesign - IEC 50 Hz/60 Hz version

Transformer	
Type description	Ecodesign dry-type cast resin transformer.
Basic layout	3 phase, 2 winding transformer.
Applied standards	IEC 60076-11, IEC 60076-16, IEC 61936-1, Commission Regulation No 548/2014.
Cooling method	AF
Rated power	4000 kVA
Rated voltage, turbine side	
U_m 1.1kV	0.650 kV
Rated voltage, grid side	
U_m 12.0kV	10.0-11.0 kV
U_m 24.0kV	11.1-22.0 kV
U_m 36.0kV	22.1-33.0 kV
U_m 40.5kV	33.1-36.0 kV
Insulation level AC / LI / LIC	
U_m 1.1kV	3[1] / - / - kV
U_m 12.0kV	28[1] / 75 / 75 kV
U_m 24.0kV	50[1] / 125 / 125 kV
U_m 36.0kV	70[1] / 170 / 170 kV
U_m 40.5kV	80[1] / 170 / 170 kV
Off-circuit tap changer	±2 x 2.5 %

Transformer	
Frequency	50 Hz / 60 Hz
Vector group	Dyn5 / YNyn0
Peak Efficiency Index (PEI) [2]	Ecodesign requirement
U_m 12.0kV	Pending
U_m 24.0kV	Pending
U_m 36.0kV	Pending
U_m 40.5kV	Pending
No-load loss [2]	
U_m 12.0kV	Pending
U_m 24.0kV	Pending
U_m 36.0kV	Pending
U_m 40.5kV	Pending
Load loss @ rated power HV, 120°C [2]	
U_m 12.0kV	Pending
U_m 24.0kV	Pending
U_m 36.0kV	Pending
U_m 40.5kV	Pending
No-load reactive power [3]	>25 kVAr
Full load reactive power [3]	>370 kVAr
No-load current [3]	0.5 %
Positive sequence short-circuit impedance @ rated power, 120°C [4]	9.0 %
Positive sequence short-circuit resistance@ rated power, 120°C [3]	0.8 %
Zero sequence short-circuit impedance@ rated power, 120°C [3]	8.2 %
Zero sequence short-circuit resistance@ rated power, 120°C [3]	0.7 %
Inrush peak current [3]	
Dyn5	6-9 x $\hat{I}_n$
YNyn0	8-12 x $\hat{I}_n$
Half crest time [3]	~ 0.7 s
Sound power level	≤ 80 dB(A)
Average temperature rise at max altitude	≤90 K
Max altitude [5]	2000 m
Insulation class	155 (F)
Environmental class	E2
Climatic class	C2
Fire behaviour class	F1
Corrosion class	C4
Weight	≤10000 kg
Temperature monitoring	PT100 sensors in LV windings and core
Overvoltage protection	Surge arresters on HV terminals
Temporary earthing	3 x Ø20 mm earthing ball points

Table 4-4: Transformer data for Ecodesign IEC 50 Hz/60 Hz version.

NOTE [1] @1000m. According to IEC 60076-11, AC test voltage is altitude dependent. All values are preliminary.
[2] For Ecodesign transformers, PEI is the legal requirement and is calculated according to the Commission Regulation based on rated power, no-load and load losses. Losses are maximum values and will not simultaneously occur in a specific design as this will be incompliant with the PEI requirement. All values are preliminary.
[3] Based on an average of calculated values across voltages and manufacturers. All values are preliminary.
[4] Subjected to standard IEC tolerances. All values are preliminary.
[5] Transformer max altitude may be adjusted to match turbine location.

4.3.3 IEEE 60Hz version

Transformer	
Type description	Dry-type cast resin transformer.
Basic layout	3 phase, 2 winding transformer.
Applied standards	UL 1562, CSA C22.2 No. 47, IEEE C57.12, IEC 60076-11, IEC 60076-16, IEC 61936-1.
Cooling method	AFA
Rated power	3750 kVA
Rated voltage, turbine side	
N_{LL} 1.2 kV	0.650 kV
Rated voltage, grid side	
N_{LL} 15.0 kV	10.0-15.0 kV
N_{LL} 25.0 kV	15.1-25.0 kV
N_{LL} 34.5 kV	25.1-34.5 kV
Insulation level AC / LI & LIC	
N_{LL} 1.2 kV	4[1] / +10 kV
N_{LL} 15.0 kV	34[1] / +95 kV
N_{LL} 25.0 kV	50[1] / +125 kV
N_{LL} 34.5 kV	70[1] / (+150 & -170) or +170 kV
Off-circuit tap changer	±2 x 2.5 %
Frequency	60 Hz
Vector group	Dyn5 / YNyn0
No-load loss [2]	>5.8 kW
Load loss @ rated power HV, 120°C [2]	>30.5 kW
No-load reactive power [2]	>16 kVAr
Full load reactive power [2]	>345 kVAr
No-load current [2]	0.5 %
Positive sequence short-circuit impedance @ rated power, 120°C [3]	9.0 %
Positive sequence short-circuit resistance @ rated power, 120°C [2]	0.7 %
Zero sequence short-circuit impedance @ rated power, 120°C [2]	8.3 %
Zero sequence short-circuit resistance @ rated power, 120°C [2]	0.7 %
Inrush peak current [2]	

Transformer	
Dyn5	$6\text{-}9 \times \hat{I}_n$
YNyn0	$8\text{-}12 \times \hat{I}_n$
Half crest time [2]	~ 0.7 s
Sound power level	≤ 80 dB(A)
Average temperature rise at max altitude	≤ 90 K
Max altitude [4]	2000 m
Insulation class	150°C
Environmental class	E2
Climatic class	C2
Fire behaviour class	F1
Corrosion class	C4
Weight	≤ 9500 kg
Temperature monitoring	PT100 sensors in LV windings and core
Overvoltage protection	Surge arresters on HV terminals
Temporary earthing	3 x Ø20 mm earthing ball points

Table 4-5: Transformer data for IEEE 60 Hz version

NOTE

[1] @1000m. According to IEEE C57.12, AC test voltage is altitude dependent. All values are preliminary.
[2] Based on an average of calculated values across voltages and manufacturers. All values are preliminary.
[3] Subjected to standard IEEE C57.12 tolerances. All values are preliminary.
[4] Transformer max altitude may be adjusted to match turbine location.

4.4 HV Cables

The high-voltage cable runs from the transformer in the nacelle down the tower to the HV switchgear located at the bottom of the tower. The high-voltage cable is a four-core, rubber-insulated, halogen-free, high-voltage cable.

HV Cables	
High-Voltage Cable Insulation Compound	Improved ethylene-propylene (EP) based material-EPR or high modulus or hard grade ethylene-propylene rubber-HEPR
Conductor Cross Section	3 x 70 / 70 mm^2
Maximum Voltage	24 kV for 10.0-22.0 kV rated voltage 42 kV for 22.1-36.0 kV rated voltage

Table 4-6: HV cables data

4.5 HV Switchgear

A gas insulated switchgear is installed in the bottom of the tower as an integrated part of the turbine. Its controls are integrated with the turbine safety system which monitors the condition of the switchgear and high voltage safety related devices in the turbine. This ensures all protection devices are fully operational whenever high voltage components in the turbine are energised. The earthing switch of the circuit breaker contains a trapped-key interlock system with its counterpart installed on the access door to the transformer room in order to avoid unauthorized access to the transformer room during live condition.

The switchgear is available in three variants with increasing features, see Table 4-7. Beside the increase in features, the switchgear can be configured depending on the number of grid cables planned to enter the individual turbine. The design of the switchgear solution is optimized such grid cables can be connected to the switchgear even before the tower is installed and still maintain its protection toward weather conditions and internal condensation due to a gas tight packing.

The switchgear is available in an IEC version and in an IEEE version. The IEEE version is however only available in the highest voltage class. The electrical parameters of the switchgear are seen in Table 4-8 for the IEC version and in Table 4-9 for the IEEE version.

HV Switchgear			
Variant	**Basic**	**Streamline**	**Standard**
IEC standards	○	⦿	⦿
IEEE standards	⦿	○	⦿
Vacuum circuit breaker panel	⦿	⦿	⦿
Overcurrent, short-circuit and earth fault protection	⦿	⦿	⦿
Disconnector / earthing switch in circuit breaker panel	⦿	⦿	⦿
Voltage Presence Indicator System for circuit breaker	⦿	⦿	⦿
Voltage Presence Indicator System for grid cables	⦿	⦿	⦿
Double grid cable connection	⦿	⦿	⦿
Triple grid cable connection	⦿	○	○
Preconfigured relay settings	⦿	⦿	⦿
Turbine safety system integration	⦿	⦿	⦿
Redundant trip coil circuits	⦿	⦿	⦿
Trip coil supervision	⦿	⦿	⦿
Pendant remote control from outside of tower	⦿	⦿	⦿
Sequential energisation	⦿	⦿	⦿
Reclose blocking function	⦿	⦿	⦿
Heating elements	⦿	⦿	⦿
Trapped-key interlock system for circuit breaker panel	⦿	⦿	⦿
UPS power back-up for protection circuits	⦿	⦿	⦿
Motor operation of circuit breaker	⦿	⦿	⦿
Cable panel for grid cables (configurable)	○	⦿	⦿
Switch disconnector panels for grid cables – max three panels (configurable)	○	⦿	⦿
Earthing switch for grid cables	○	⦿	⦿
Internal arc classification	○	⦿	⦿
Supervision on MCB's	○	⦿	⦿
Motor operation of switch disconnector	○	○	⦿
SCADA ready	○	○	⦿
SCADA operation of circuit breaker	○	○	⦿
SCADA operation of switch disconnector	○	○	⦿

Table 4-7: HV switchgear variants and features.

4.5.1 IEC 50/60Hz version

HV Switchgear	
Type description	Gas Insulated Switchgear
Applied standards	IEC 62271-103 IEC 62271-1, 62271-100, 62271-102, 62271-200, IEC 60694
Insulation medium	SF_6
Rated voltage	
U_r 24.0kV	10.0-22.0 kV
U_r 36.0kV	22.1-33.0 kV
U_r 40.5kV	33.1-36.0 kV
Rated insulation level AC // LI Common value / across isolation distance	
U_r 24.0kV	50 / 60 // 125 / 145 kV
U_r 36.0kV	70 / 80 // 170 / 195 kV
U_r 40.5kV	85 / 90 // 185 / 215 kV
Rated frequency	50 Hz / 60 Hz
Rated normal current	630 A
Rated Short-time withstand current	
U_r 24.0kV	20 kA
U_r 36.0kV	25 kA
U_r 40.5kV	25 kA
Rated peak withstand current 50 / 60 Hz	
U_r 24.0kV	50 / 52 kA
U_r 36.0kV	62.5 / 65 kA
U_r 40.5kV	62.5 / 65 kA
Rated duration of short-circuit	1 s
Internal arc classification (option)	
U_r 24.0kV	IAC A FLR 20 kA, 1 s
U_r 36.0kV	IAC A FLR 25 kA, 1 s
U_r 40.5kV	IAC A FLR 25 kA, 1 s
Connection interface	Outside cone plug-in bushings, IEC interface C1.
Loss of service continuity category	LSC2
Ingress protection	
Gas tank	IP 65
Enclosure	IP 2X
LV cabinet	IP 3X
Corrosion class	C3

Table 4-8: HV switchgear data for IEC version.

4.5.2 IEEE 60Hz version

HV Switchgear	
Type description	Gas Insulated Switchgear
Applied standards	IEEE 37.20.3, IEEE C37.20.4, IEC 62271-200, ISO 12944.
Insulation medium	SF_6
Rated voltage	
U_r 38.0kV	22.1-36.0 kV

HV Switchgear	
Rated insulation level AC / LI	70 / 150 kV
Rated frequency	60 Hz
Rated normal current	600 A
Rated Short-time withstand current	25 kA
Rated peak withstand current	65 kA
Rated duration of short-circuit	1 s
Internal arc classification (option)	IAC A FLR 25 kA, 1 s
Connection interface grid cables	Outside cone plug-in bushings, IEEE 386 interface type deadbreak, 600A.
Ingress protection	
Gas tank	NEMA 4X / IP 65
Enclosure	NEMA 2 / IP 2X
LV cabinet	NEMA 2 / IP 3X
Corrosion class	C3

Table 4-9: HV switchgear data for IEEE version.

4.6 AUX System

The AUX system is supplied from a separate 650/400 V transformer located in the nacelle. All motors, pumps, fans and heaters are supplied from this system.

All 230 V consumers are supplied from a 400/230 V transformer located in the tower base.

Power Sockets	
Single Phase (Nacelle and Tower Platforms)	230 V (16 A)/110 V (16 A)/ 2 x 55 V (16 A)
Three Phase (Nacelle and Tower Base)	3 x 400 V (16 A)

Table 4-10: AUX system data

4.7 Wind Sensors

The turbine is either equipped with two ultrasonic wind sensors or optional one ultrasonic wind sensor and one mechanical wind vane and anemometer. The sensors have built-in heaters to minimise interference from ice and snow. The wind sensors are redundant, and the turbine is able to operate with one sensor only.

4.8 Vestas Multi Processor (VMP) Controller

The turbine is controlled and monitored by the System 8000 control system.

System 8000 is a multiprocessor control system comprised of main controller, distributed control nodes, distributed IO nodes and ethernet switches and other network equipment. The main controller is placed in the tower bottom of the turbine. It runs the control algorithms of the turbine, as well as all IO communication.

The communications network is a time triggered Ethernet network (TTEthernet).

The System 8000 control system serves the following main functions:

- Monitoring and supervision of overall operation.
- Synchronizing of the generator to the grid during connection sequence.
- Operating the wind turbine during various fault situations.
- Automatic yawing of the nacelle.
- OptiTip® - blade pitch control.
- Reactive power control and variable speed operation.
- Noise emission control.
- Monitoring of ambient conditions.
- Monitoring of the grid.
- Monitoring of the smoke detection system.

4.9 Uninterruptible Power Supply (UPS)

During grid outage, an UPS system will ensure power supply for specific components.

The UPS system is built by 3 subsystems:

1. 230V AC UPS for all power backup to nacelle and hub control systems
2. 24V DC UPS for power backup to tower base control systems and optional SCADA Power Plant Controller.
3. 230V AC UPS for power backup to internal lights in tower and nacelle. Internal light in the hub is fed from built-in batteries in the light armature.

UPS		
Backup Time	**Standard**	**Optional**
Control System* **(230V AC and 24V DC UPS)**	15 min	Up to 400 min**
Internal Lights **(230V AC UPS)**	30 min	60 min***
Optional SCADA Power Plant Controller **(24V DC UPS**	N/A	48 hours****

Table 4-11: UPS data

**The control system includes: the turbine controller (VMP6000), HV switchgear functions, and remote control system.*

***Requires upgrade of the 230V UPS for control system with extra batteries.*

****Requires upgrade of the 230V UPS for internal light with extra batteries.*

*****Requires upgrade of the 24V DC UPS with extra batteries.*

NOTE For alternative backup times, consult Vestas.

5 Turbine Protection Systems

5.1 Braking Concept

The main brake on the turbine is aerodynamic. Stopping the turbine is done by full feathering the three blades (individually turning each blade). Each blade has a hydraulic accumulator to supply power for turning the blade.

In addition, there is a mechanical disc brake on the high-speed shaft of the gearbox with a dedicated hydraulic system. The mechanical brake is only used as a parking brake and when activating the emergency stop buttons.

5.2 Short Circuit Protections

Breakers	Breaker for Aux. Power. (not settled)	Breaker for Converter Modules (not settled)
Breaking Capacity, Icu, Ics	TBD	TBD
Making Capacity, Icm	TBD	TBD

Table 5-1: Short circuit protection data

5.3 Overspeed Protection

The generator rpm and the main shaft rpm are registered by inductive sensors and calculated by the wind turbine controller to protect against overspeed and rotating errors.

In addition, the turbine is equipped with a safety PLC, an independent computer module that measures the rotor rpm. In case of an overspeed situation, the safety PLC activates the emergency feathered position (full feathering) of the three blades independently of the turbine controller.

Overspeed Protection	
Sensors Type	Inductive
Trip Level (variant dependent)	15.3-17.6 rpm / 2000 (generator rpm)

Table 5-3: Overspeed protection data

5.4 Arc Detection

The turbine is equipped with an Arc Detection system including multiple optical arc detection sensors placed in the HV transformer compartment and the grid interface cabinet. The Arc Detection system is connected to the turbine safety system ensuring immediate opening of the HV switchgear if an arc is detected.

5.5 Smoke Detection

The turbine is equipped with a Smoke Detection system including multiple smoke detection sensors placed in the nacelle (above the disc brake), in the transformer compartment, in main electrical cabinets in the nacelle and above the HV switchgear in the tower base. The Smoke Detection system is connected to the turbine safety system ensuring immediate opening of the HV switchgear if smoke is detected.

5.6 Lightning Protection of Blades, Nacelle, Hub and Tower

The Lightning Protection System (LPS) helps protect the wind turbine against the physical damage caused by lightning strikes. The LPS consists of five main parts:

- Lightning receptors.
- Down conducting system (a system to conduct the lightning current down through the wind turbine to help avoid or minimise damage to the LPS itself or other parts of the wind turbine).
- Protection against overvoltage and overcurrent.
- Shielding against magnetic and electrical fields.
- Earthing system.

Lightning Protection Design Parameters			**Protection Level I**
Current Peak Value	i_{max}	[kA]	200
Impulse Charge	$Q_{impulse}$	[C]	100
Long Duration Charge	Q_{long}	[C]	200
Total Charge	Q_{total}	[C]	300
Specific Energy	W/R	[MJ/Ω]	10
Average Steepness	di/dt	[kA/μs]	200

Table 5-4: Lightning protection design parameters

NOTE The Lightning Protection System is designed according to IEC standards (see section 8 Design Codes, p. 28).

5.7 EMC System

The turbine and related equipment fulfils the EU Electromagnetic Compatibility (EMC) legislation:

- DIRECTIVE 2004/108/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 15 December 2004 on the approximation of the laws of the Member States relating to electromagnetic compatibility and repealing Directive 89/336/EEC.

5.8 Earthing

The Vestas Earthing System consists of a number of individual earthing electrodes interconnected as one joint earthing system.

The Vestas Earthing System includes the TN-system and the Lightning Protection System for each wind turbine. It works as an earthing system for the medium voltage distribution system within the wind farm.

The Vestas Earthing System is adapted for the different types of turbine foundations. A separate set of documents describe the earthing system in detail, depending on the type of foundation.

In terms of lightning protection of the wind turbine, Vestas has no separate requirements for a certain minimum resistance to remote earth (measured in ohms) for this system. The earthing for the lightning protection system is based on the design and construction of the Vestas Earthing System.

A primary part of the Vestas Earthing System is the main earth bonding bar placed where all cables enter the wind turbine. All earthing electrodes are connected to this main earth bonding bar. Additionally, equipotential connections are made to all cables entering or leaving the wind turbine.

Requirements in the Vestas Earthing System specifications and work descriptions are minimum requirements from Vestas and IEC. Local and national requirements, as well as project requirements, may require additional measures.

5.9 Corrosion Protection

Classification of corrosion protection is according to ISO 12944-2.

Corrosion Protection	External Areas	Internal Areas
Nacelle	C5-M	C3
Hub	C5-M	C3
Tower	C5-I	C3

Table 5-5: Corrosion protection data for nacelle, hub, and tower

6 Safety

The safety specifications in this section provide limited general information about the safety features of the turbine and are not a substitute for Buyer and its agents taking all appropriate safety precautions, including but not limited to (a) complying with all applicable safety, operation, maintenance, and service agreements, instructions, and requirements, (b) complying with all safety-related laws, regulations, and ordinances, and (c) conducting all appropriate safety training and education.

6.1 Access

Access to the turbine from the outside is through a door located at the entrance platform approximately 3 meter above ground level. The door is equipped with a lock. Access to the top platform in the tower is by a ladder or service lift. Access to the nacelle from the top platform is by ladder. Access to the transformer room in the nacelle is controlled with a lock. Unauthorised access to electrical switchboards and power panels in the turbine is prohibited according to IEC 60204-1 2006.

6.2 Escape

In addition to the normal access routes, alternative escape routes from the nacelle are through the crane hatch, from the spinner by opening the nose cone, or from the roof of the nacelle. Rescue equipment is placed in the nacelle.

The hatch in the roof can be opened from both the inside and outside.

Escape from the service lift is by ladder.

An emergency response plan, placed in the turbine, describes evacuation and escape routes.

6.3 Rooms/Working Areas

The tower and nacelle are equipped with power sockets for electrical tools for service and maintenance of the turbine.

6.4 Floors, Platforms, Standing, and Working Places

All floors have anti-slip surfaces.

There is one floor per tower section.

Rest platforms are provided at intervals of 9 metres along the tower ladder between platforms.

Foot supports are placed in the turbine for maintenance and service purposes.

6.5 Service Lift

The turbine is delivered with a service lift installed as an option.

6.6 Climbing Facilities

A ladder with a fall arrest system (rigid rail) is installed through the tower.

There are anchor points in the tower, nacelle and hub, and on the roof for attaching fall arrest equipment (full-body harness).

Over the crane hatch there is an anchor point for the emergency descent equipment.

Anchor points are coloured yellow and are calculated and tested to 22.2 kN.

6.7 Moving Parts, Guards, and Blocking Devices

All moving parts in the nacelle are shielded.

The turbine is equipped with a rotor lock to block the rotor and drive train.

Blocking the pitch of the cylinder can be done with mechanical tools in the hub.

6.8 Lights

The turbine is equipped with lights in the tower, nacelle, transformer room, and hub.

There is emergency light in case of the loss of electrical power.

6.9 Emergency Stop

There are emergency stop buttons in the nacelle, hub and bottom of the tower.

6.10 Power Disconnection

The turbine is equipped with breakers to allow for disconnection from all power sources during inspection or maintenance. The switches are marked with signs and are located in the nacelle and bottom of the tower.

6.11 Fire Protection/First Aid

A handheld 5-6 kg CO_2 fire extinguisher, first aid kit and fire blanket are required to be located in the nacelle during service and maintenance.

- A handheld 5-6 kg CO_2 fire extinguisher is required only during service and maintenance activities, unless a permanently mounted fire extinguisher located in the nacelle is mandatorily required by authorities.
- First aid kits are required only during service and maintenance activities.
- Fire blankets are required only during non-electrical hot work activities.

6.12 Warning Signs

Warning signs placed inside or on the turbine must be reviewed before operating or servicing the turbine.

6.13 Manuals and Warnings

The Vestas Corporate OH&S Manual and manuals for operation, maintenance and service of the turbine provide additional safety rules and information for operating, servicing or maintaining the turbine.

7 Environment

7.1 Chemicals

Chemicals used in the turbine are evaluated according to the Vestas Wind Systems A/S Environmental System certified according to ISO 14001:2004. The following chemicals are used in the turbine:

- Anti-freeze to help prevent the cooling system from freezing.
- Gear oil for lubricating the gearbox.
- Hydraulic oil to pitch the blades and operate the brake.
- Grease to lubricate bearings.
- Various cleaning agents and chemicals for maintenance of the turbine.

8 Design Codes

8.1 Design Codes – Structural Design

The turbine design has been developed and tested with regard to, but not limited to, the following main standards:

Design Codes	
Nacelle and Hub	IEC 61400-1 Edition 3 EN 50308
Tower	IEC 61400-1 Edition 3 Eurocode 3
Blades	DNV-OS-J102 IEC 1024-1 IEC 60721-2-4 IEC 61400 (Part 1, 12 and 23) IEC WT 01 IEC DEFU R25 ISO 2813 DS/EN ISO 12944-2
Gearbox	ISO 81400-4
Generator	IEC 60034
Transformer	IEC 60076-11, IEC 60076-16, CENELEC HD637 S1
Lightning Protection	IEC 62305-1: 2006 IEC 62305-3: 2006 IEC 62305-4: 2006 IEC 61400-24:2010
Rotating Electrical Machines	IEC 34
Safety of Machinery, **Safety-related Parts of Control Systems**	IEC 13849-1
Safety of Machinery – Electrical Equipment of Machines	IEC 60204-1

Table 8-1: Design codes

9 Colours

9.1 Nacelle Colour

Colour of Vestas Nacelles	
Standard Nacelle Colour	RAL 7035 (light grey)

Colour of Vestas Nacelles	
Standard Logo	Vestas

Table 9-1: Colour, nacelle

9.2 Tower Colour

Colour of Vestas Tower Section		
	External:	**Internal:**
Standard Tower Colour	RAL 7035 (light grey)	RAL 9001 (cream white)

Table 9-2: Colour, tower

9.3 Blade Colour

Blade Colour	
Standard Blade Colour	RAL 7035 (light grey)
Tip-End Colour Variants	RAL 2009 (traffic orange), RAL 3020 (traffic red)
Gloss	< 30% DS/EN ISO 2813

Table 9-3: Colour, blades

10 Operational Envelope and Performance Guidelines

Actual climate and site conditions have many variables and should be considered in evaluating actual turbine performance. The design and operating parameters set forth in this section do not constitute warranties, guarantees, or representations as to turbine performance at actual sites.

10.1 Climate and Site Conditions

Values refer to hub height:

Extreme Design Parameters	
Wind Climate	**All**
Ambient Temperature Interval (Standard Temperature Turbine)	-40° to +50°C

Table 10-1: Extreme design parameters

10.2 Operational Envelope – Temperature

Values refer to hub height and are determined by the sensors and control system of the turbine.

Operational Envelope – Temperature	
Ambient Temperature Interval (Standard Turbine)	-20° to +45°C
Ambient Temperature Interval (Low Temperature Turbine)	-30° to +45°C

Table 10-2: Operational envelope - temperature

NOTE At ambient temperatures above +30°C, the turbine will maintain derated production, within the component capacity as seen in figure 9-1. For 3.6 MW Power Mode, derated production will start from +20°C.

The wind turbine will stop producing power at ambient temperatures above 45°C.

For the low temperature options of the wind turbine, consult Vestas.

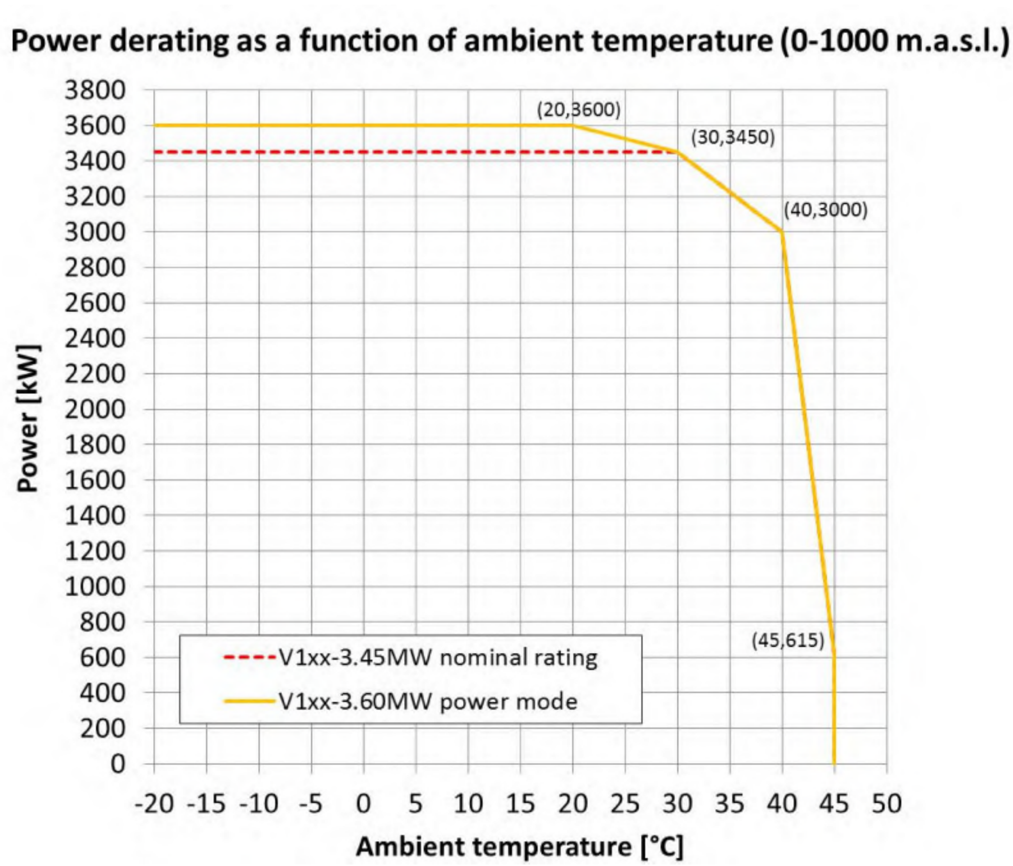

Figure 9-1: Derated operation for 3.45 MW rating and 3.6 MW Power Mode

10.3 Operational Envelope – Grid Connection

Operational Envelope – Grid Connection		
Nominal Phase Voltage	[U_{NP}]	650 V
Nominal Frequency	[f_N]	50/60 Hz
Maximum Frequency Gradient	±4 Hz/sec.	
Maximum Negative Sequence Voltage	3% (connection) 2% (operation)	
Minimum Required Short Circuit Ratio at Turbine HV Connection	5.0	
Maximum Short Circuit Current Contribution	1.05 p.u. (continuous) 1.45 p.u. (peak)	

Table 10-3: Operational envelope – grid connection

The generator and the converter will be disconnected if*:

Protection Settings	
Voltage Above 110% of Nominal for 3600 Seconds**	715 V
Voltage Above 121% of Nominal for 2 Seconds	787 V
Voltage Above 136% of Nominal for 0.150 Seconds	884 V
Voltage Below 90% of Nominal for 60 Seconds**	585 V
Voltage Below 80% of Nominal for 10 Seconds	520 V
Frequency is Above 106% of Nominal for 0.2 Seconds	53/63.6 Hz
Frequency is Below 94% of Nominal for 0.2 Seconds	47/56.4 Hz

Table 10-4: Generator and converter disconnecting values

NOTE

* Over the turbine lifetime, grid drop-outs are to occur at an average of no more than 50 times a year.

** The turbine may be configured for continuous operation @ +/- 13 % voltage. Reactive power capability is limited for these widened settings (See section 9.4).

10.4 Operational Envelope – Reactive Power Capability

The 3.45 MW turbine has a reactive power capability on the low voltage side of the HV transformer as illustrated in Figure 9-4.:

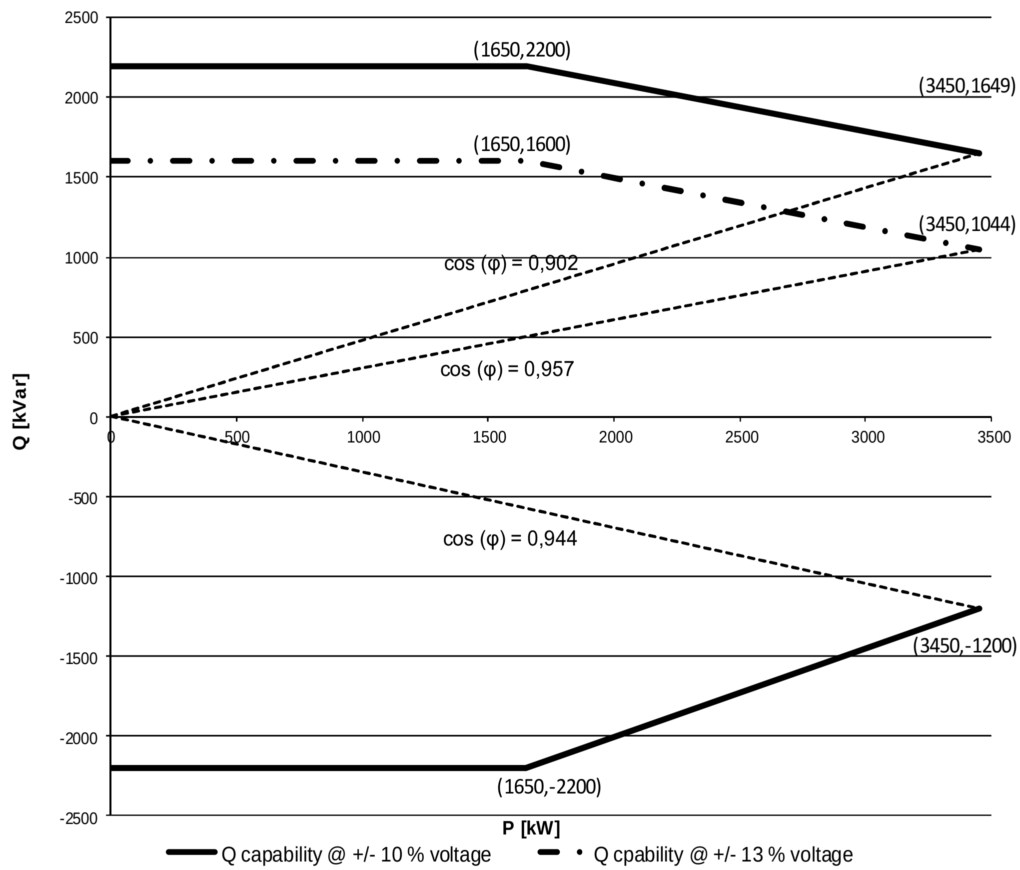

Figure 10-4: Reactive power capability for 3.45 MW rating

Reactive power capability at full load on high voltage side of the HV transformer is approximately: cosφ = 0.93/0.92 capacitive/inductive @ +/- 10 % voltage and 0.98/0.92 capacitive/inductive @ +/- 13 % voltage.

Reactive power is produced by the full-scale converter. Traditional capacitors are, therefore, not used in the turbine.

The turbine is able to maintain the reactive power capability at low wind with no active power production.

The reactive power capability for 3.6 MW Power Mode is pending finalization.

10.5 Performance – Fault Ride Through

The turbine is equipped with a full-scale converter to gain better control of the wind turbine during grid faults. The turbine control system continues to run during grid faults.

The turbine is designed to stay connected during grid disturbances within the voltage tolerance curve as illustrated:

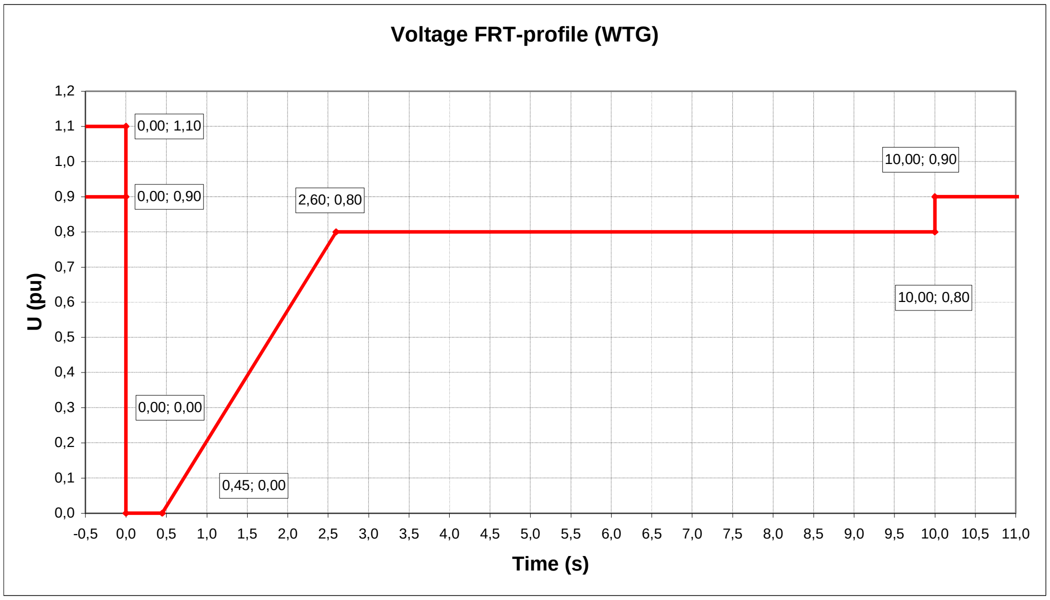

Figure 10-5: Low voltage tolerance curve for symmetrical and asymmetrical faults, where U represents voltage as measured on the grid

For grid disturbances outside the tolerance curve in Figure 10-5, the turbine will be disconnected from the grid.

Power Recovery Time	
Power Recovery to 90% of Pre-Fault Level	Maximum 0.1 seconds

Table 10-5: Power recovery time

10.6 Performance – Reactive Current Contribution

The reactive current contribution depends on whether the fault applied to the turbine is symmetrical or asymmetrical.

10.6.1 Symmetrical Reactive Current Contribution

During symmetrical voltage dips, the wind farm will inject reactive current to support the grid voltage. The reactive current injected is a function of the measured grid voltage.

The default value gives a reactive current part of 1 pu of the rated active current at the high voltage side of the HV transformer. Figure 10-6, indicates the reactive current contribution as a function of the voltage. The reactive current contribution is independent from the actual wind conditions and pre-fault power level.

As seen in Figure 10-5, the default current injection slope is 2% reactive current increase per 1% voltage decrease. The slope can be parameterized between 0 and 10 to adapt to site specific requirements.

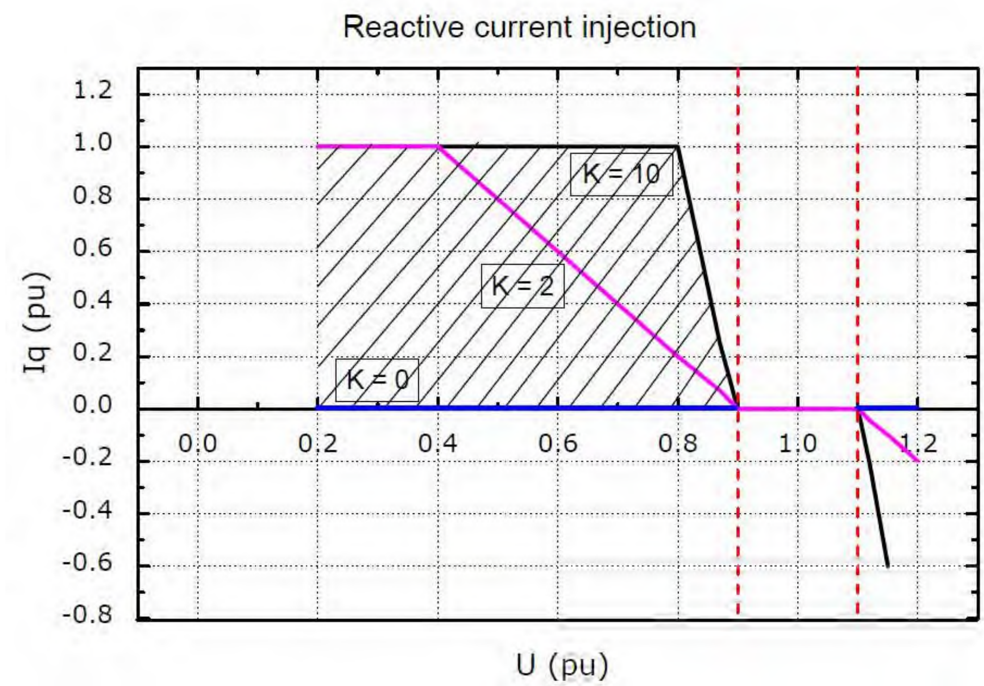

Figure 10-6: Reactive current injection

10.6.2 Asymmetrical Reactive Current Contribution

The injected current is based on the measured positive sequence voltage and the used K-factor. During asymmetrical voltage dips, the reactive current injection is limited to approximate 0.4 pu to limit the potential voltage increase on the healthy phases.

10.7 Performance – Multiple Voltage Dips

The turbine is designed to handle re-closure events and multiple voltage dips within a short period of time due to the fact that voltage dips are not evenly distributed during the year. For example, the turbine is designed to handle 10 voltage dips of duration of 200 ms, down to 20% voltage, within 30 minutes.

10.8 Performance – Active and Reactive Power Control

The turbine is designed for control of active and reactive power via the VestasOnline® SCADA system.

Maximum Ramp Rates for External Control	
Active Power	0.1 pu/sec (345 kW/s) for max. power level change of 0.3 pu (1035 kW) 0.3 pu/sec (1035 kW/s) for max. power level change of 0.1 pu (345 kW)
Reactive Power	20 pu/sec

Table 10-6: Active/reactive power ramp rates (values are preliminary)

To support grid stability the turbine is capable to stay connected to the grid at active power references down to 10 % of nominal power for the turbine. For active power references below 10 % the turbine may disconnect from the grid.

10.9 Performance – Voltage Control

The turbine is designed for integration with VestasOnline® voltage control by utilising the turbine reactive power capability.

10.10 Performance – Frequency Control

The turbine can be configured to perform frequency control by decreasing the output power as a linear function of the grid frequency (over frequency).

Dead band and slope for the frequency control function are configurable.

10.11 Main Contributors to Own Consumption

The consumption of electrical power by the wind turbine is defined as the power used by the wind turbine when it is not providing energy to the grid. This is defined in the control system as Production Generator 0 (zero).The following components have the largest influence on the own consumption of the wind turbine (the average own consumption depends on the actual conditions, the climate, the wind turbine output, the cut-off hours, etc.):

Main contributors to Own Consumption	
Hydraulic Motor	2 x 15 kW (master/slave)
Yaw Motors	Maximum 18 kW in total
Water Heating	10 kW
Water Pumps	2.2 + 5.5 kW
Oil Heating	7.9 kW
Oil Pump for Gearbox Lubrication	10 kW
Controller Including Heating Elements for the Hydraulics and all Controllers	Approximately 3 kW
HV Transformer No-load Loss	See section 4.3 HV Transformer, p. 13

Table 10-7: Main contributors to own consumption data (values are preliminary)

11 Drawings

11.1 Structural Design – Illustration of Outer Dimensions

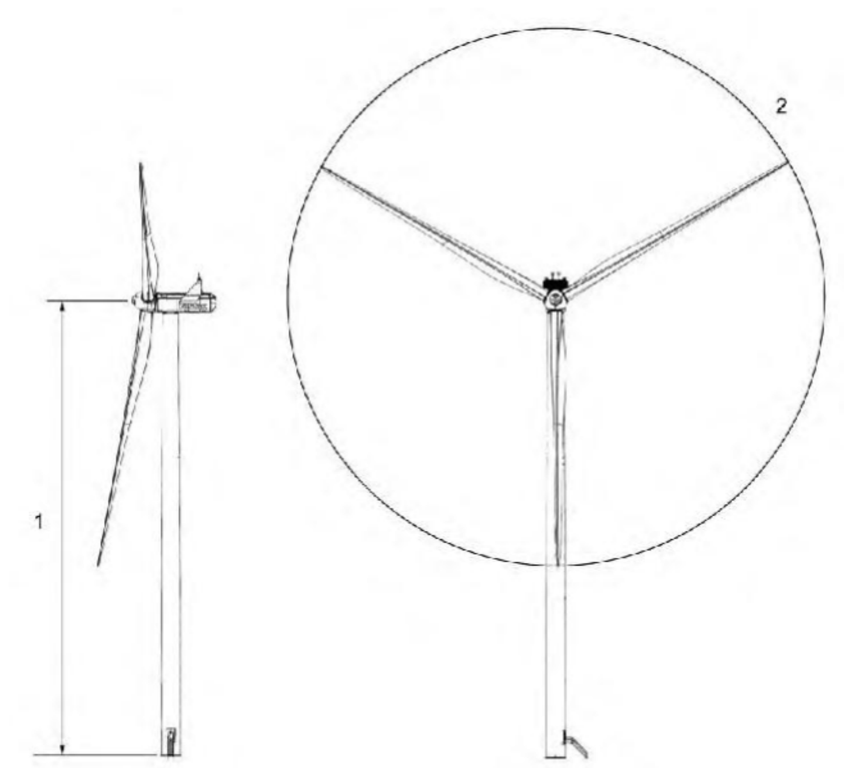

Figure 11-1: Illustration of outer dimensions – structure

1 Hub heights: See Performance Specification

2 Rotor diameter: 105-136 m

11.2 Structural Design – Side View Drawing

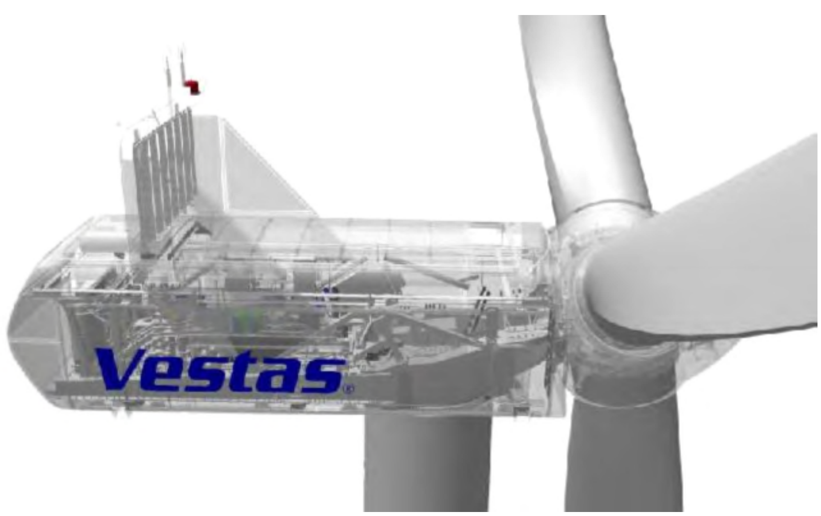

Figure 11-2: Side-view drawing

12 General Reservations, Notes and Disclaimers

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- The general descriptions in this document apply to the current version of the 3MW Platform wind turbines. Updated versions of the 3MW Platform wind turbines, which may be manufactured in the future, may differ from this general description. In the event that Vestas supplies an updated version of a specific 3MW Platform wind turbine, Vestas will provide an updated general description applicable to the updated version.
- Vestas recommends that the grid be as close to nominal as possible with limited variation in frequency and voltage.
- A certain time allowance for turbine warm-up must be expected following grid dropout and/or periods of very low ambient temperature.
- All listed start/stop parameters (e. g. wind speeds and temperatures) are equipped with hysteresis control. This can, in certain borderline situations, result in turbine stops even though the ambient conditions are within the listed operation parameters.
- The earthing system must comply with the minimum requirements from Vestas, and be in accordance with local and national requirements and codes of standards.
- This document, General Description, is not an offer for sale, and does not contain any guarantee, warranty and/or verification of the power curve and noise (including, without limitation, the power curve and noise verification method). Any guarantee, warranty and/or verification of the power curve and noise (including, without limitation, the power curve and noise verification method) must be agreed to separately in writing.