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# General Description

## EnVentus™

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# 1 Introduction

This *General Description* contains data and general descriptions of the EnVentus™ wind turbine range. The EnVentus™ turbine range consists of various turbine variants, with different rotors and ratings.

For turbine variant specific information related to wind class definitions and performance details, please refer to the accompanying Performance Specification document.

# 2 General Description

A wind turbine within the EnVentus™ turbine range is a pitch regulated upwind turbine with active yaw and a three-blade rotor.

The wind turbine utilises the OptiTip® concept and a power system based on a permanent magnet generator and full-scale converter. With these features, the wind turbines are 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.

# 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 | V150 | V162 |
|---|---|---|
| **Diameter** | 150 m | 162 m |
| **Swept Area** | 17671 $m^2$ | 20612 $m^2$ |
| **Speed, Dynamic Operation Range** | 4.9 - 12.6 rpm | 4.3 -12.1 rpm |
| **Rotational Direction** | Clockwise (front view) | |
| **Orientation** | Upwind | |
| **Tilt** | 6° | |
| **Hub Coning** | 6° | |
| **No. 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 with embedded structure.

| Blades | V150 | V162 |
|---|---|---|
| **Blade Length** | 73.65 m | 79.35 m |
| **Maximum Chord** | 4.2 m | 4.3 m |
| **Chord at 90% blade radius** | 1.4 m | 1.68 m |
| **Type Description** | Structural airfoil shell | |
| **Material** | Fibreglass reinforced epoxy, carbon fibres and Solid Metal Tip (SMT) | |
| **Blade Connection** | Steel roots inserted | |
| **Airfoils** | High-lift profile | |

*Table 3-2: Blades data*

## 3.3 Blade Bearing

The blade bearings allow the blades to operate at varying pitch angles.

| Blade Bearing | |
|---|---|
| **Blade bearing type** | High-capacity slewing bearing |
| **Lubrication** | Manual grease lubrication |

*Table 3-3: Blade bearing data*

## 3.4 Pitch System

The turbine is equipped with a hydraulic, individual pitch system for each blade. Each pitch system is connected to the hydraulic rotating transfer unit in the nacelle by means of distributed hydraulic hoses and pipes. The hydraulic power unit is positioned in the nacelle.

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

| **Pitch System** | |
|---|---|
| **Type** | Hydraulic |
| **Number** | 1 cylinder per blade |
| **Range** | -5° to 95° |

*Table 3-4: Pitch system data*

| **Hydraulic System** | |
|---|---|
| **Main Pump** | Redundant internal-gear oil pumps |
| **Pressure** | Max. 260 bar |
| **Filtration** | 3 µm (absolute)<br>40 µm in line |

*Table 3-5: Hydraulic system data.*

## 3.5 Hub

The hub supports the three blades and transfers the reaction loads and the torque to the Main Shaft. The hub structure also supports blade bearings and pitch cylinders.

| **Hub** | |
|---|---|
| **Type** | 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 carries the main bearings and is the connection point for the drive train system to the nacelle structure.

| Main Bearing Housing | |
|---|---|
| **Material** | Cast iron |

*Table 3-8: Main bearing housing data*

## 3.8 Main Bearing

The main bearings constitute the main load transfer path for the rotor and drivetrain to the nacelle structure.

| Main Bearing | |
|---|---|
| **Type** | Rolling bearings |
| **Lubrication** | Oil circulation |

*Table 3-9: Main bearing data*

## 3.9 Gearbox

The main gear converts the rotation of the rotor to generator rotation.

| Gearbox | |
|---|---|
| **Type** | 2 Planetary stages |
| **Gear House Material** | Cast |
| **Lubrication System** | Pressure oil lubrication |
| **Total Gear Oil Volume** | 800-1000 L |
| **Oil Cleanliness Codes** | ISO 4406-/15/12 |

*Table 3-10: Gearbox data*

## 3.10 Generator Bearings

Generator bearings ensures a constant airgap between the generator rotor and stator. The bearings are arranged in an assembly that allows for up-tower service.

| Generator Bearing | |
|---|---|
| **Type** | Rolling bearings |
| **Lubrication** | Oil circulation |

*Table 3-11: Generator bearing data*

## 3.11 Yaw System

The yaw system is an active system based on a pre-tensioned plain bearing.

| Yaw System | |
|---|---|
| **Type** | Plain bearing system |
| **Material** | Forged yaw ring heat-treated.<br>Plain bearings PETP |
| **Yaw gear type** | Multiple stages planetary gear |
| **Yawing Speed (50 Hz)** | Approx. 0.4°/sec. |
| **Yawing Speed (60 Hz)** | Approx. 0.5°/sec. |

*Table 3-12: Yaw system data*

## 3.12 Crane

The nacelle is equipped with an internal service crane (single system hoist).

| Crane | |
|---|---|
| **Lifting Capacity** | HH<149 m max 500 kg<br>HH>149 m max 800 kg |

*Table 3-13: Crane data*

## 3.13 Towers

Tubular Steel Towers and Concrete Hybrid Towers (CHT) are available as standard for several WTG configuration and hub height options.

Tubular steel towers consist of flange joined steel sections.

Concrete Hybrid Towers consists of a concrete bottom part with a transition piece towards a tubular steel top. The concrete part is made of precast high strength concrete rings, and the tubular steel top is made of flange joined steel sections.

Towers includes modular internals, which are certified to relevant type approvals.

Available hub heights are listed in the Performance Specification for each turbine variant. Designated hub heights include a distance from tower top flange to centre of the hub of approximately 2.5m. For steel towers the designated hub height also includes a distance from the foundation section to the ground level of approximately 0.2 m depending on the thickness of the bottom flange.

For steel towers, raised foundations of up to 3 m can be made available on a site-specific basis subject to soil and project conditions which raises the hub height also by up to 3m.

Further WTG configuration and hub height options are developed as non-standard products on site-specific basis.

| Towers | |
|---|---|
| **Type** | Tubular steel towers<br>Larger diameter steel towers<br>Concrete Hybrid Towers |

Table 3-14: Tower structure data

## 3.14 Nacelle Structure and Cover

The nacelle structure is in two parts and consists of a cast iron front part, the base frame, and a girder structure rear part, the rear structure. The base frame 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 base frame.

The crane girders are attached to the rear structure.

The nacelle cover is attached to the nacelle structure. 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 skylights.

The skylights can be opened from inside the nacelle to access the roof and from outside to access the nacelle. Access from the tower to the nacelle is through the base frame.

| Type Description | Material |
|---|---|
| **Nacelle Cover** | GRP |
| **Base frame** | Cast iron |
| **Rear structure** | Girder structure |

*Table 3-15: Nacelle structure and cover data*

## 3.15 Thermal Conditioning System

The thermal conditioning system consists of:

- A Liquid Cooling System
- The Vestas Cooler Top®
- Air cooling of the nacelle internal, and
- Air cooling of the converter including a filter function

### 3.15.1 Liquid Cooling

The liquid cooling system removes the heat losses from the gearbox, generator, hydraulic power unit, converter and the HV transformer.

The liquid cooling system pump unit includes a set of dynamic flow valves securing the right flow to the different systems. The pump unit also includes a heater for pre-heating the liquid in cold start-up situations, an electrical controlled valve for controlling the liquid temperature and a bypass filter for removal of particles in the cooling liquid.

### 3.15.2 Cooler Top®

The Vestas Cooler Top® located on top of the rear end of the nacelle. The Cooler Top® is a free flow cooler, thus ensuring that there are no electrical components in the thermal conditioning system located outside the nacelle. The Cooler Top® serves as base for the wind sensors, ice detection sensor, aviation lights and visibility sensor.

### 3.15.3 Nacelle Conditioning

Hot air generated by mechanical and electrical equipment is dissipated from the nacelle by a fan system located in the nacelle. The nacelle conditioning is taking ambient air into the nacelle and exhaust the hot air in the end of the nacelle.

### 3.15.4 Converter Air Cooling

The converter is both liquid and air cooled. The converter air cooling system comprises an air to air heat exchanger, which separates ambient air from converter internal air. The ambient air flow is provided by fan units delivering ambient air to the air to air heat exchanger through a filter. Fans on the internal side of the air to air exchanger provides the converter internal air circulation.

# 4 Electrical Design

## 4.1 Generator

The generator is a three-phase permanent magnet generator connected to the grid through a full-scale converter. The generator housing allows the circulation of cooling air within the stator and rotor.

The heat generated by the losses is removed by an air-to-water heat exchanger.

| *Generator* | |
|---|---|
| **Type** | Permanent Magnet Synchronous generator |
| **Rated Power [$P_N$]** | Up to 6450 kW (depending on turbine variant) |
| **Frequency range [$f_N$]** | 0-138 Hz |
| **Voltage, Stator [$U_{NS}$]** | 3 x 800 V (at rated speed) |
| **Number of Poles** | 36 |
| **Winding Type** | Form with Vacuum Pressurized Impregnation |
| **Winding Connection** | Star |
| **Operational speed range** | 0-460 rpm |
| **Overspeed Limit (2 minutes)** | 720 rpm |
| **Temperature Sensors, Stator** | PT100 sensors placed in the stator hot spots. |
| **Insulation Class** | 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 delivered to the grid. The converter consists of 4 machine-side converter units and 4 line-side converter units operating in parallel with a common controller.

The converter controls conversion of variable frequency AC 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 720 V. The generator side voltage rating is nominally 800 V but depends on generator speed.

| **Converter** | |
|---|---|
| **Rated Apparent Power [$S_N$] @ 1.0 p.u. voltage** | 6750 kVA |
| **Rated Grid Voltage** | 3 x 720 V |
| **Rated Generator Voltage** | 3 x 800 V |
| **Rated Grid Current @ 1.0 p.u. voltage** | 5400 A |
| **Enclosure** | IP54 |

*Table 4-2: Converter data*

## 4.3 HV Transformer

The transformer is a three-phase, three limb, two-winding, liquid immersed transformer. The transformer is equipped with an external water-cooling circuit. The insulation liquid used is environmentally friendly and low flammable.

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

The transformer is designed according to IEC standards and is available in the following version:

- Eco-design complying to Tier 2 of European Ecodesign regulation No 548/2014 and No 2019/1783 set by the European Commission. Refer to Table 4-3.

### 4.3.1 General transformer data

| **Transformer** | | | |
|---|---|---|---|
| **Type description** | Eco-design liquid immersed transformer. | | |
| **Basic layout** | 3 phase, 2 winding transformer | | |
| **Applied standards** | IEC 60076-1, IEC 60076-16, IEC 61936-1<br>Commission Regulation No 548/2014<br>Commission Regulation No 2019/1783 | | |
| **Cooling method** | KF/WF | | |
| **Rated power** | 7000 kVA | 7300kVA | 7500kVA |
| **Expansion system** | Open breathing | Sealed | Sealed |
| **Insulation liquid, Type/Fire point** | Synthetic ester, biodegradable/ K-class (>300°C) | Natural/Synthetic ester, biodegradable/ K-class (>300°C) | |
| **No-load reactive power** | ~17 kVAr [1] | ~18 kVAr [1] | ~19 kVAr [1] |
| **Full load reactive power** | ~735 kVAr [1] | ~810 kVAr[1] | ~832 kVAr[1] |
| **No-load current** | ~ 0.25 % [1] | ~ 0.25 % [1] | ~ 0.25 % [1] |

| **Transformer** | | | |
|---|---|---|---|
| **Positive sequence short-circuit impedance @ rated power, 95°C** | 9.9 % [2] | 10.3 % [2] | 10.6 % [2] |
| **Positive sequence short-circuit resistance@ rated power, 95°C** | ~0.9 % [1] | ~0.9 % [1] | ~0.9 % [1] |
| **Zero sequence short-circuit impedance@ rated power, 95°C** | ~9.6 % [1] | ~10.0 % [1] | ~10.3 % [1] |
| **Zero sequence short-circuit resistance@ rated power, 95°C** | ~0.9 % [1] | ~0.9 % [1] | ~0.9 % [1] |
| **Rated voltage, turbine side** | | | |
| **$U_m$ 1.1kV** | 0.720 kV | | |
| **Rated voltage, grid side** | | | |
| **$U_m$ 24.0kV** | 20.0-22.0 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 / - / - kV | | |
| **$U_m$ 24.0kV** | 50 / 125 / 138 kV | | |
| **$U_m$ 36.0kV** | 70 / 170 / 187 kV | | |
| **$U_m$ 40.5kV** | 80 / 200 / 220 kV | | |
| **Off-circuit tap changer** | None | | |
| **Frequency** | 50 Hz / 60 Hz | | |
| **Vector group** | Dyn11 | | |
| **Inrush peak current** | <8 x $\hat{I}_n$ [1] | | |
| **Half crest time** | ~ 0.5 s [1] | | |
| **Sound power level** | ≤ 80 dB(A) | | |
| **Average winding temperature rise** | Class 120 (E) ≤65 K<br>Class 130 (B) ≤75 K | | |
| **Max altitude** | 3500 m | | |
| **Insulation system** | Hybrid insulation system<br>Winding insulation:<br>120 (E), Thermally Upgrader Paper<br>130 (B), High temperature insulation<br>Other materials can have different class. | | |
| **Insulation liquid, Amount** | ≤ 3000 kg | | |
| **Corrosion class** | C3 | | |
| **Weight** | ≤11200 kg | | |
| **Overvoltage protection** | Plug-in surge arresters on HV bushings | | |
| **High voltage bushings** | Outer cone, interface C1 | | |

*Table 4-3: General transformer data.*

### 4.3.2 Eco-design – IEC 50 Hz/60 Hz version

The transformer loss limits are given at rated power as combination of load loss and no-load loss which shall fulfil the Peak Efficiency Index (PEI) of the Eco-design requirement.
The maximum losses are described by the PEI limit section of Figure 4-1, Figure 4-2 and Figure 4-3 and stretch over a range between Loss variant 1 and Loss variant 2.
The loss variant values are selected based on energy loss optimization with the turbine user profile, hence the energy loss of transformers between Loss variant 1 and Loss variant 2 are comparable.

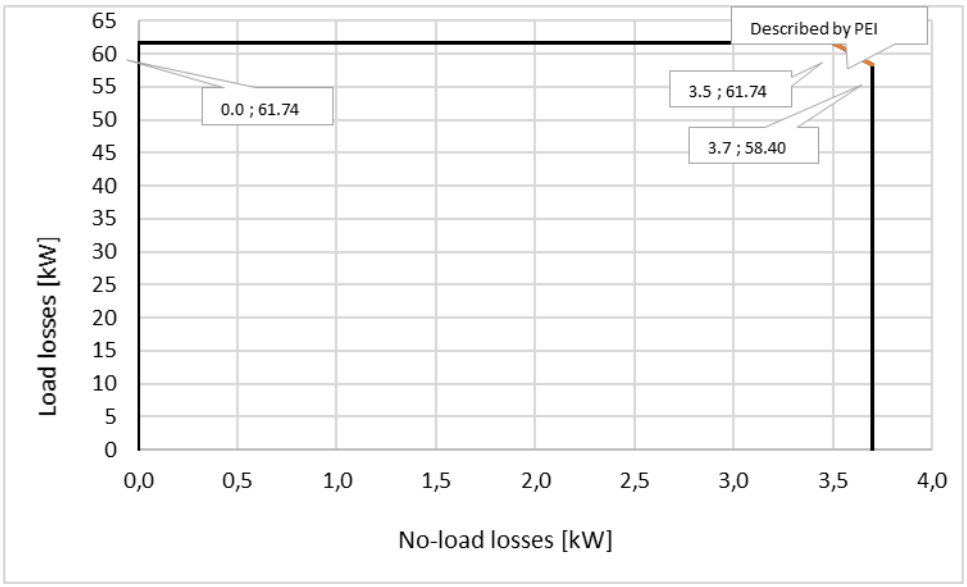



*Figure 4-1: Transformer losses allowable area for 7000kVA variant*

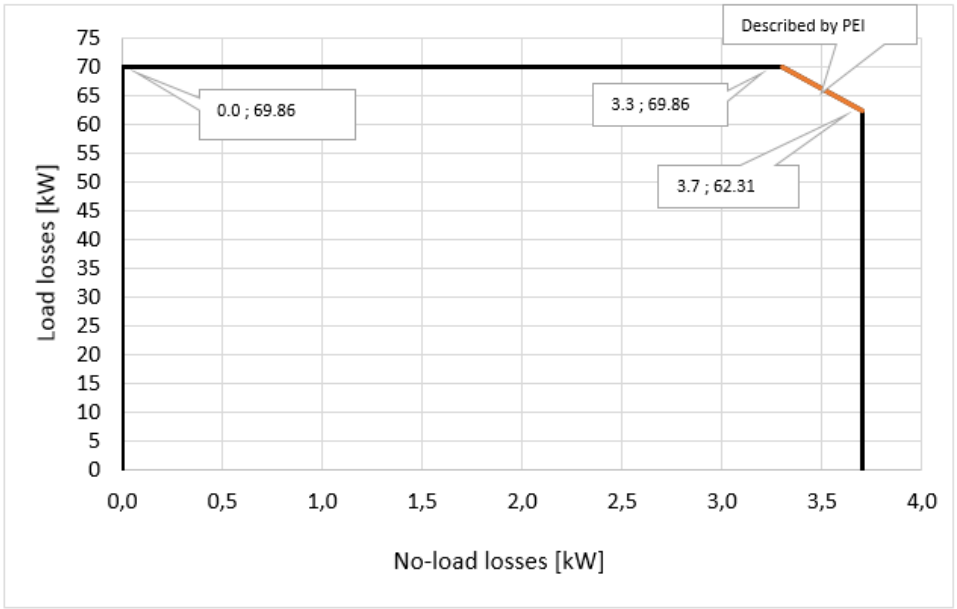



*Figure 4-2: Transformer losses allowable area for 7300kVA variant*

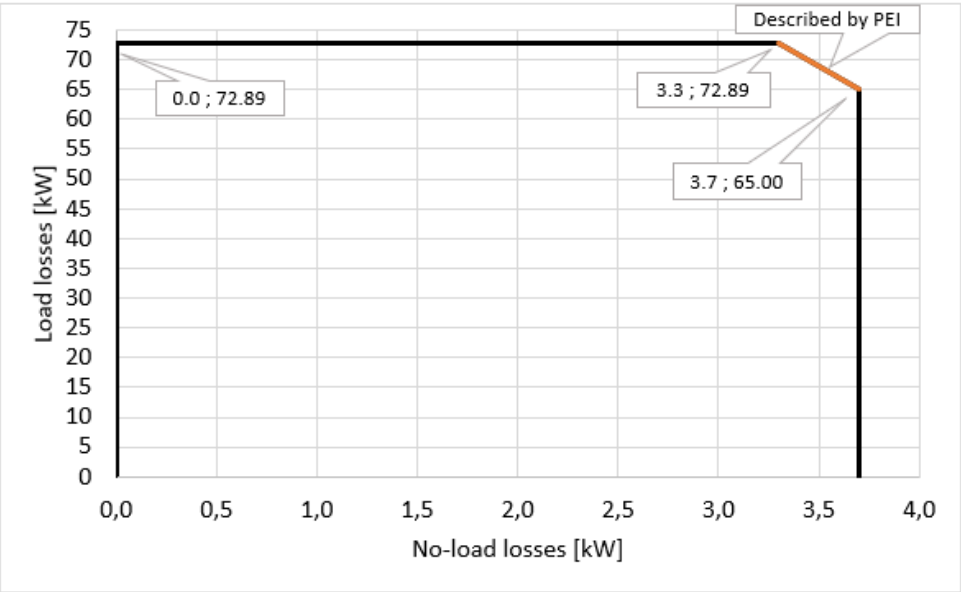



*Figure 4-3: Transformer losses allowable area for 7500kVA variant*

The actual load losses vary depending on the operational mode of the turbine, hence in *Table 4-4*, *Table 4-5* and *Table 4-6*, the load losses are provided at different operational modes for the two loss variants. For further recalculation of load losses at different operation modes, refer to Figure 4-4.

| **Transformer losses (rated power 7000kVA)** | | | | |
|---|---|---|---|---|
| **Applied standards** | Commission Regulation No 2019/1783 | | | |
| **Peak Efficiency Index (PEI)** | ≥ 99.580 | | | |
| **Loss variant 1** | | | | |
| **No-load loss** | 3.50 kW | | | |
| **Load loss @ power, 95°C** | **@7000kVA** | **@5600kVA** | **@5400kVA** | **@5000kVA** |
| | ≤61.74kW | ≤39.51kW [3] | ≤36.74kW [3] | ≤31.50kW [3] |
| **Loss variant 2** | | | | |
| **No-load loss** | 3.70 kW | | | |
| **Load loss @ power, 95°C** | **@7000kVA** | **@5600kVA** | **@5400kVA** | **@5000kVA** |
| | ≤58.40kW | ≤37.38kW[3] | ≤34.75kW[3] | ≤29.80kW[3] |

*Table 4-4: Transformer losses for 7000kVA version*

| **Transformer losses (rated power 7300kVA)** | | | |
|---|---|---|---|
| **Applied standards** | Commission Regulation No 2019/1783 | | |
| **Peak Efficiency Index (PEI)** | ≥ 99.584 | | |
| **Loss variant 1** | | | |
| **No-load loss** | 3.30 kW | | |
| **Load loss @ power, 95°C** | **@7300kVA** | **@6000kVA** | **@5600kVA** |
| | ≤69.86kW | ≤47.19kW [3] | ≤41.11kW [3] |
| **Loss variant 2** | | | |
| **No-load loss** | 3.70 kW | | |
| **Load loss @ power, 95°C** | **@7300kVA** | **@6000kVA** | **@5600kVA** |
| | ≤62.31kW | ≤42.09kW[3] | ≤36.67kW[3] |

*Table 4-5: Transformer losses for 7300kVA version*

| **Transformer losses (rated power 7500kVA)** | | | | |
|---|---|---|---|---|
| **Applied standards** | Commission Regulation No 2019/1783 | | | |
| **Peak Efficiency Index (PEI)** | ≥ 99.586 | | | |
| **Loss variant 1** | | | | |
| **No-load loss** | 3.30 kW | | | |
| **Load loss @ power, 95°C** | **@7500kVA** | **@6200kVA** | **@6000kVA** | **@5600kVA** |
| | ≤72.89kW | ≤49.81kW | ≤46.65kW [3] | ≤40.64kW [3] |
| **Loss variant 2** | | | | |
| **No-load loss** | 3.70 kW | | | |
| **Load loss @ power, 95°C** | **@7500kVA** | **@6200kVA** | **@6000kVA** | **@5600kVA** |
| | ≤65.00kW | ≤44.42kW | ≤41.60kW[3] | ≤36.24kW[3] |

*Table 4-6: Transformer losses for 7500kVA version*


*Figure 4-4: Transformer load losses scaling*

**NOTE**

[1] Based on an average of calculated values across voltages and manufacturers.
[2] Subjected to standard IEC tolerances.
[3] Informative non-binding values based on operation mode.

## 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 can be of two different constructions:

- A three-core, rubber-insulated, halogen-free, high-voltage cable with a three-core split earth conductor.
- 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 |
| **Pre-terminated** | T-Connector Type-C in transformer end.<br>T-Connector Type-C in switchgear end. |
| **Maximum Voltage** | 24 kV for 19.1-22.0 kV rated voltage<br>42 kV for 22.1-36.0 kV rated voltage |
| **Conductor Cross Sections** | 3x70 + 70 $mm^2$ (Single PE core)<br>3x70 + 3x70/3 $mm^2$ (Split PE core) |

*Table 4-7: 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 system is named ‘Ready to Protect’ and ensures all protection devices are operational, whenever high voltage components in the turbine are energised. To ensure that the switchgear is always ready to trip, it is equipped with redundant trip circuits consisting of an active trip coil and an undervoltage trip coil.

In case of grid outage, the circuit breaker will disconnect the turbine from the grid after an adjustable time.

When grid returns, all relevant protection devices will automatically be powered up via UPS.

When all the protection devices are operational, the circuit breaker will re-close after an adjustable time. The re-close functionality can furthermore be used to implement a sequential energization of a wind park, in order to avoid simultaneous inrush currents from all turbines once grid returns after an outage.

In case the circuit breaker has tripped due to a fault detection, the circuit breaker will be blocked for re-connection until a manual reset is performed.

In order to avoid unauthorized access to the transformer room during live condition, 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.

The switchgear is available in three variants with increasing features, see Table 4-8. 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 4-9 for the IEC version and in Table 4-10 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 energization | ⊙ | ⊙ | ⊙ |
| Reclose blocking function | ⊙ | ⊙ | ⊙ |
| Heating elements | ⊙ | ⊙ | ⊙ |
| Trapped-key interlock system for circuit breaker panel | ⊙ | ⊙ | ⊙ |
| 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 | ○ | ○ | ⊙ |

| HV Switchgear | | | |
|---|---|---|---|
| **Variant** | **Basic** | **Streamline** | **Standard** |
| SCADA operation and feedback of circuit breaker | ○ | ○ | ⊙ |
| SCADA operation and feedback of switch disconnector | ○ | ○ | ⊙ |

*Table 4-8: HV switchgear variants and features*

### 4.5.1 IEC 50/60Hz version

| HV Switchgear | |
|---|---|
| **Type description** | Gas Insulated Switchgear |
| **Applied standards** | IEC 62271-103<br>IEC 62271-1, 62271-100, 62271-102, 62271-200 |
| **Insulation medium** | $SF_6$ |
| **Rated voltage** | |
| **$U_r$ 24.0kV** | 19.1-22.0 kV |
| **$U_r$ 36.0kV** | 22.1-33.0 kV |
| **$U_r$ 40.5kV** | 33.1-36.0 kV |
| **Rated insulation level AC // LI<br>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<br>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 4-9: 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 |
| **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 4-10: HV switchgear data for IEEE version*

## 4.6 AUX System

The AUX system is supplied from a separate 720/400 V transformer located in the nacelle. The supply to this transformer primary side is provided from converter cabinet. All auxiliary loads in the turbine such as motors, pumps, fans and heaters are supplied from this system.

The control system (DCN's) is also supplied from the Auxiliary Power System in all areas of the turbine.

The 400 V supply from Nacelle is transferred to Tower controller cabinet, which is placed at the entrance platform of the turbine. This supply is then distributed for various 400 & 230 V loads such as service lift, working light system, additional / optional features & general-purpose loads, cabinet internal heating & ventilation. There is a 400/230 V control transformer placed inside tower cabinet which provides supply to the UPS cabinet which is placed very near to the tower cabinet.

There is a 400 V service inlet provided in the tower control cabinet to connect an external power source that allows some of the systems to operate during installation & maintenance / service activities.

The working & emergency light system in Tower & Nacelle is supplied from a small control cabinet which is placed in the entrance platform just beside the turbine entrance door. It is possible to add an optional battery cabinet to the light cabinet if extended back-up time is needed. The internal light in the hub is fed from built-in batteries in the light armature.

| **Power Sockets** | |
|---|---|
| **Single Phase (Nacelle)** | 230 V (16 A) (standard)<br>110 V (16 A) (option) |
| **Single Phase (Tower Platforms)** | 230 V (10 A) (standard)<br>110 V (16 A) (option) |
| **Three Phase (Nacelle)** | 3 x 400 V (16 A) |

*Table 4-11: AUX system data*

## 4.7 Wind Sensors

The turbine is equipped with one ultrasonic wind sensor and one mechanical wind vane. The sensors have built-in heaters to minimise interference from ice and snow.

## 4.8 Vestas Multi Processor (VMP) Controller

The turbine is controlled and monitored by the VMP8000 control system.

VMP8000 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 VMP8000 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 designed according to EN54 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 ready to protect.
3. 230V AC UPS for power backup to internal lights in tower, nacelle and hub.

| **UPS** | | |
|---|---|---|
| **Backup Time** | **Standard** | **Optional** |
| **Control System*** **(230V AC and 24V DC UPS)** | Up to 30 min | Up to 19.5 hours** |
| **Emergency Lights** **(230V AC UPS)** | 30 min | 60 min*** |
| **Ready to protect** **(24V DC UPS)** | 7 days | 37 days**** |

*Table 4-12: UPS data*

**The control system includes: the turbine controller (VMP8000), 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.*

It is possible to add optional battery cabinets with UPS for extended back-up time.

**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 hydraulic activated mechanical disc brake on the medium-speed shaft of the gearbox. 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. | Breaker 1 for Converter Modules | Breaker 2 for Converter Modules |
|---|---|---|---|
| **Breaking Capacity Icu, Ics** | Icu 80 kA<br>Ics 75% Icu | Icu 78 kA<br>Ics 50% Icu | 78 kA<br>Ics 50% Icu |
| **Making Capacity Icm** | 193 kA | 193 kA | 193 kA |

*Table 5-1: Short circuit protection data*

## 5.3 Overspeed Protection

The safety system integrated in the VMP8000 control system monitors the rotor speed, using a combination of sensors in the hub. In case of an overspeed situation, the safety system activates the hydraulic safety pitch system, which will feather the blades and bring the turbine to standstill.

| Overspeed Protection | |
|---|---|
| **Sensor Type** | MEMS |
| **Trip Level** | Variant dependent |

*Table 5-2: 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 converter 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, in the transformer compartment, in main electrical cabinets in the nacelle and 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:

- Air termination system e.g. lightning receptors. All lightning receptor surfaces on the blades are unpainted, excluding the Solid Metal Tips (SMT).
- 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 |
| **Total Charge** | $Q_{total}$ | [C] | 300 |
| **Specific Energy** | W/R | [MJ/Ω] | 10 |
| **Average Steepness** | di/dt | [kA/µs] | 200 |

*Table 5-3: Lightning protection design parameters (IEC)*

## 5.7 EMC

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

- DIRECTIVE 2014/30/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 26 February 2014 on the harmonisation of the laws of the Member States relating to electromagnetic compatibility.

The EMC performance is based on fulfilment of following standards:

**Emission**

- IEC/CISPR 11 at wind turbine level
- IEC 61000-6-4 for telecommunications

**Immunity**

- IEC 61000-6-2 for electronics installed
- IEC 61400-24 for lightning protection of electronics installed

Beside DIRECTIVE 2014/30/EU, electronics related to the functional safety evaluation shall fulfil

- IEC 62061 Safety on machinery (Directive 2006/42/EU Machinery)

## 5.8 RED (Radio Equipment Directive)

Related radio equipment installed in the turbine fulfil the EU legislation:

DIRECTIVE 2014/53/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 16 April 2014.

## 5.9 EMF (ElectroMagnetic Fields)

Electromagnetic fields in the wind turbine are identified to ensure safe stay for personnel during design, production, operation and service.

The following directive is basis for ensuring minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents.

DIRECTIVE 2013/35/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 26 June 2013.

## 5.10 Earthing

The Vestas Earthing System consists 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.

## 5.11 Corrosion Protection

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

| Corrosion Protection | External Areas | Internal Areas |
|---|---|---|
| **Nacelle** | C5 | C3 |
| **Hub** | C5 | C3 |
| **Tower** | C5 | 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 meters 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 an interlock. Unauthorised access to electrical switchboards and power panels in the turbine is prohibited according to IEC 60204-1 2006.

## 6.2 Escape

The primary evacuation route is through the tower via the tower ladder. In case the tower is blocked the secondary option is to descent directly from nacelle to ground via the service hatch.

It is a prerequisite that one or more descent devices are available in the turbine when there are people present in the turbine. A dedicated attachment point for a descent device is provided above the hatch.

For rescue the normal access routes can be used, in addition to this it is possible to lower an injured person to the ground through the crane hatch, the hatch in the spinner or from the nacelle roof.

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

## 6.5 Service Lift

The service lift can be delivered as an option Please contact Vestas for additional details.

## 6.6 Work restraint and fall arrest

The tower ladder is equipped with a fall arrest system, either a rigid anchor line or a wire

The service areas in the turbines are equipped with anchor points. The anchor point may be used for work positioning, fall restraint, fall arrest and to attach a descent device to perform rescue or escape from the turbine.

Anchor points are coloured yellow and are tested to 22.5 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 blade can be done both automatically and manually with a mechanical blade lock.

## 6.8 Lights

The turbine is equipped with lights in the tower, nacelle 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 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

When there are people present in the turbine following fire and safety equipment must be available. In the nacelle: A first aid kit, a handheld fire extinguisher, and a fire blanket. In the tower a handheld fire extinguisher and a fire blanket at the entrance platform.

## 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 14001:2015. The following chemicals are used in the turbine:

- Anti-freeze to help prevent the cooling system from freezing.
- Gear oil for lubricating the main bearing, gearbox and generator
- Hydraulic oil to pitch the blades and operate the brake.
- Grease for yaw system lubrication
- Transformer insulation liquid for HV transformer
- 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 verified in accordance with, but not limited to, the following main standards:

| Design Codes | |
|---|---|
| **Nacelle and Hub** | IEC 61400-1 Edition 4<br>EN 50308 |
| **Tower (IEC)** | IEC 61400-1 Edition 4 |
| **Tower (DIBt)** | IEC 61400-1 Edition 3<br>Richtlinie für Windenergieanlagen, DIBt, Ausgabe: Oktober 2012 |
| **Blades** | DNV-OS-J102<br>IEC 1024-1<br>IEC 60721-2-4<br>IEC 61400 (Part 1, 12 and 23)<br>DEFU R25<br>DS/EN ISO 12944-2 |
| **Gearbox** | IEC 61400-4 |
| **Generator** | IEC 60034 (relevant parts) |
| **Transformer** | IEC 60076-11, IEC 60076-16, CENELEC HD637 S1 |
| **Lightning Protection** | IEC 61400-24:2019 |
| **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) |
| **Standard Logo** | Vestas |

*Table 9-1: Colour, nacelle*

## 9.2 Tower Colour

| Colour of Vestas Tower Section | | |
|---|---|---|
| | **External:** | **Internal:** |
| **Standard Steel Tower** | RAL 7035 (light grey) | RAL 9001 (cream white) |
| **Standard Concrete Hybrid Tower** | **Concrete part:** Unpainted concrete, corresponds approx. to RAL 7023 (concrete grey) **Steel part:** RAL 7035 (light grey) | **Concrete part:** Unpainted concrete, corresponds approx. to RAL 7023 (concrete grey) **Steel part**: RAL 9001 (cream white) |
| **Option for Concrete Hybrid Tower** | Concrete part can be painted with RAL 7035 (light grey) | |

*Table 9-2: Colour, tower*

## 9.3 Blade Colour

| Blade Colour | |
|---|---|
| **Standard Blade Colour** | RAL 7035 (light grey). All lightning receptor surfaces on the blades are unpainted, excluding the Solid Metal Tips (SMT). |
| **Tip-End Colour Variants** | RAL 2009 (traffic orange), RAL 3020 (traffic red) |
| **Gloss** | < 30% 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 and Altitude

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

| **Operational Envelope – Temperature** | |
|---|---|
| **Ambient Temperature Interval** | -20° to +45°C |
| **Ambient Temperature Interval (Low Temperature Operation)** | -30° to +45°C |

*Table 10-2: Operational envelope – temperature*

**NOTE**

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

For turbine variant specific information related to power performance within the operational envelope, please refer to turbine variant specific Performance Specifications.

For the low temperature operation of the wind turbine, consult Vestas for site specific evaluation.

The turbine is designed for use at altitudes up to 1000 m above sea level as standard and optional up to 2000 m above sea level.

## 10.3 Operational Envelope – Grid Connection

| Operational Envelope – Grid Connection | | |
|---|---|---|
| **Nominal Phase Voltage** | [$U_{NP}$] | 720 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 (contact Vestas for lower SCR levels) | |
| **Maximum Short Circuit Current Contribution** | Contact Vestas for details | |

*Table 10-3: Operational envelope – grid connection*

The generator and the converter will be disconnected if*:

| Protection Settings | |
|---|---|
| **Voltage Above 110%** of Nominal for 1800 Seconds** | 792 V |
| **Voltage Above 116% of Nominal for 60 Seconds** | 835 V |
| **Voltage Above 125% of Nominal for 2 Seconds** | 900 V |
| **Voltage Above 136% of Nominal for 0.150 Seconds** | 979 V |
| **Voltage Below 90%** of Nominal for 180 Seconds (FRT)** | 648 V |
| **Voltage Below 85% of Nominal for 12 Seconds (FRT)** | 612 V |
| **Voltage Below 80% of Nominal for 4.8 Seconds (FRT)** | 576 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 to an extent that is yet to be determined.

## 10.4 Operational Envelope – Reactive Power Capability

For turbine variant specific reactive power capability, please refer to the variant specific Performance Specification.

## 10.5 Performance – Fault Ride Through

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

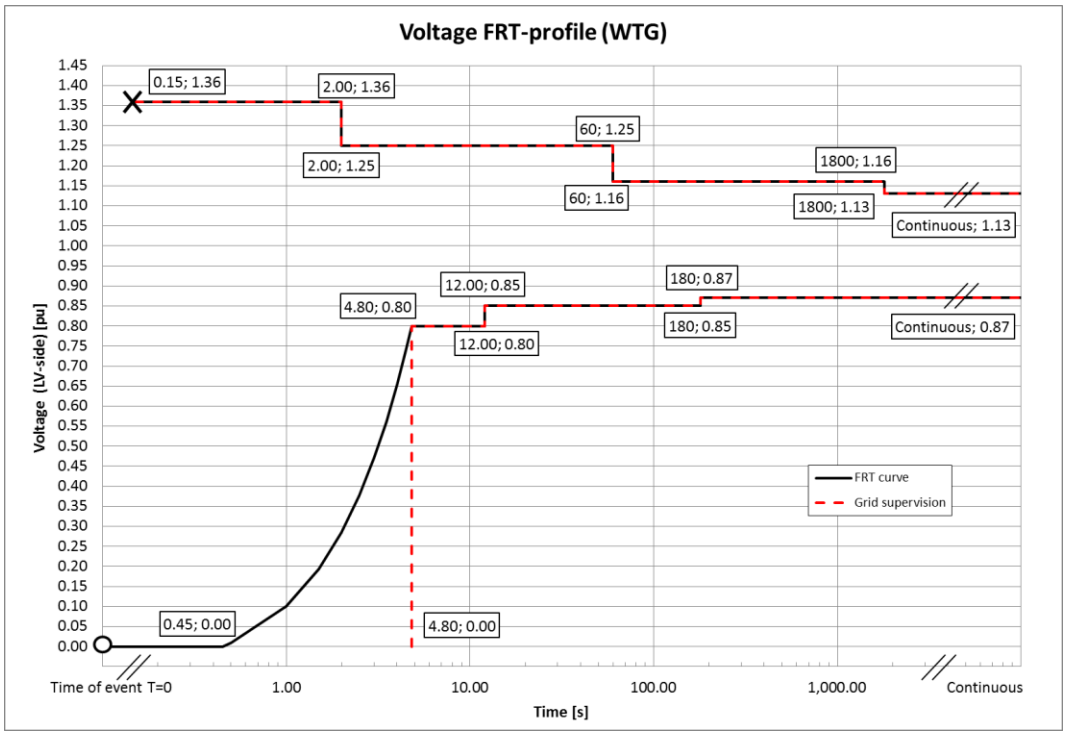



*Figure 10-1: Voltage tolerance curve for symmetrical and asymmetrical faults, where U represents voltage as measured on the grid.*

For grid disturbances outside the tolerance curve in Figure 10-1, 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 p.u. of the rated active current at the high voltage side of the HV transformer. Figure 10-2, 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 10-2, 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.

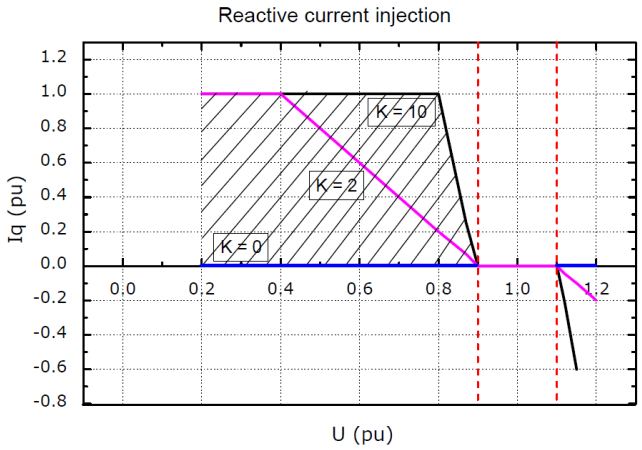



*Figure 10-2: Reactive current injection*

### 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 p.u. 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 p.u./sec for max. power level change of 0.3 p.u.<br>0.3 p.u./sec for max. power level change of 0.1 p.u. |
| **Reactive Power** | 20 p.u./sec |

*Table 10-6: Active/reactive power ramp rates*

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 Distortion – Immunity

The turbine is able to connect with a pre-connection (background) voltage distortion level at the grid interface of 8% and operate with a post-connection voltage distortion level of 8%.

## 10.12 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 VMP8000 control system has a hibernate mode that reduces own consumption when possible. Similarly, cooling pumps may be turned off when the turbine idles.

The components in Table 10-7 have the largest influence on the own consumption of the wind turbine. The values given are maximum component consumption, but the average consumption can be lower depending on the actual conditions, the climate, the wind turbine output, the cut-off hours, etc.

| Main contributors to Own Consumption | V150 | V162 |
|---|---|---|
| **Hydraulic Motor** | 2 x 22 kW | 3 x 18.5 kW |
| **Yaw Motors** | Max 23 kW | Max 26 kW |
| **Generator Cooling Fans** | 4 x 2.5 kW | |
| **Water Pumps** | 4 kW + 7.5 kW | |
| **Oil Pump for Gearbox Lubrication** | 7.5 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 | |

*Table 10-7: Main contributors to own consumption data.*

# 11 Drawings

## 11.1 Structural Design – Illustration of Outer Dimensions

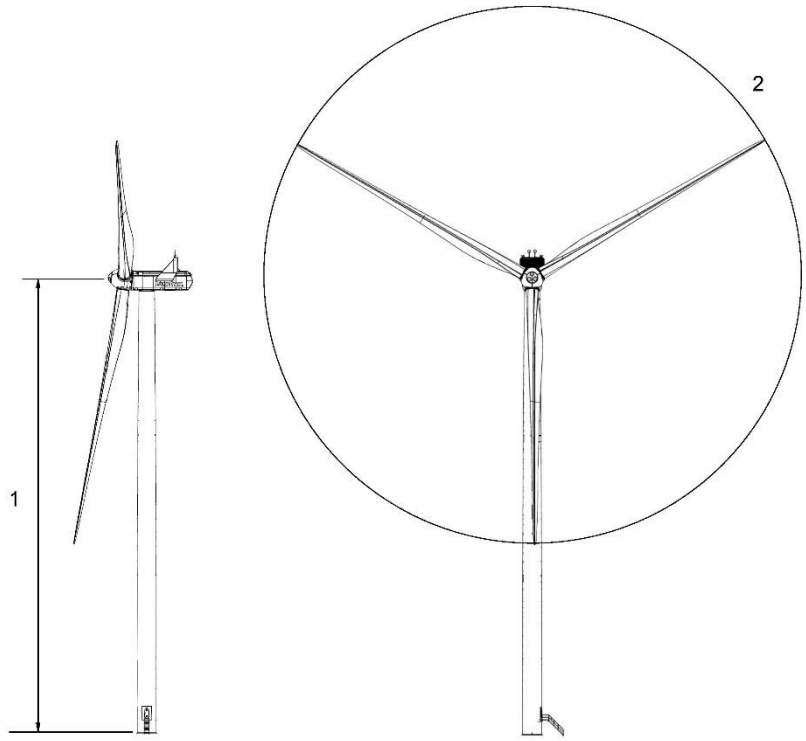



*Figure 11-1: Illustration of outer dimensions – structure*

**1** Hub heights: See Performance Specification **2** Rotor diameter: 150/162 m

## 12 General Reservations, Notes and Disclaimers

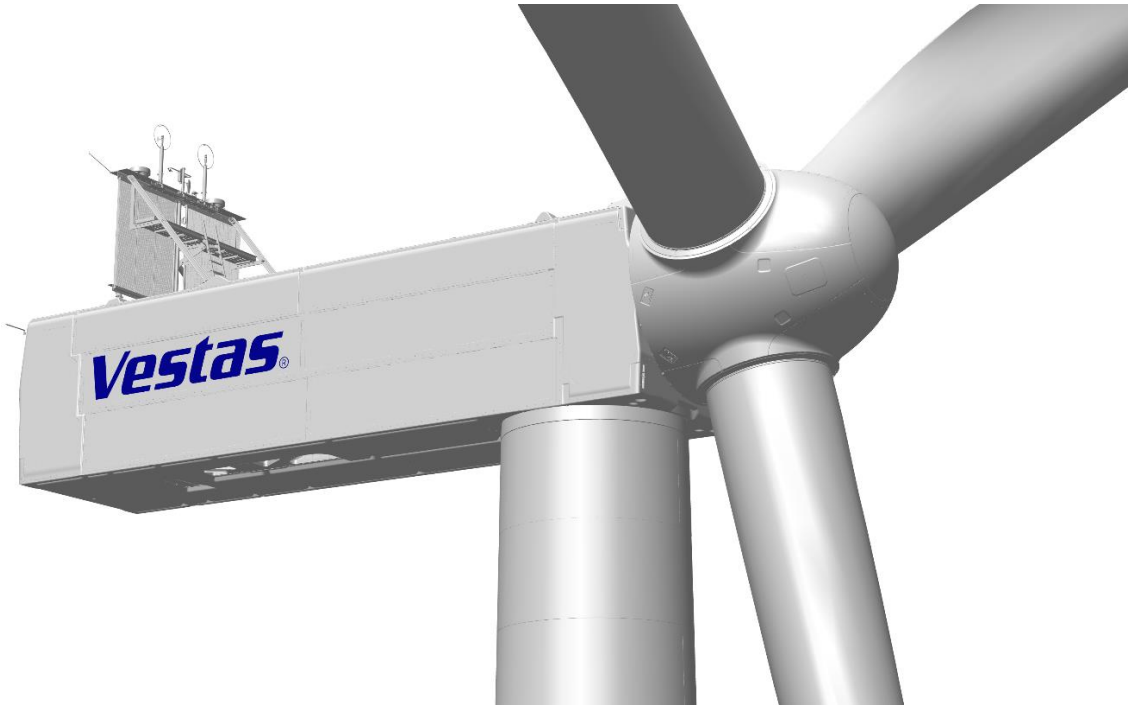

- The general descriptions in this document apply to the current version of the EnVentus™ turbines. Updated versions of the EnVentus™ turbines, which may be manufactured in the future, may differ from this general description. In the event that Vestas supplies an updated version of the EnVentus™ turbine, Vestas will provide an updated general description applicable to the updated version.
- Vestas recommends that the grid shall 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.

Restricted
Document no.: 0098-0749 V01
2020-10-13

# Performance Specification

## EnVentus™

## V150-6.0 MW 50/60 Hz



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**See general reservations, notes and disclaimers (including, Section 5, p. 12) to this Performance Specification.**

# 1 General Description

The Vestas V150-6.0 MW is a wind turbine variant within the EnVentus™ turbine range. It is a pitch regulated upwind turbine with active yaw and a three-blade rotor. The V150-6.0 MW turbine has a rotor diameter of 150 m and a rated power of 6.0 MW.

For more details, please refer to the General Description of the EnVentus™ turbine range (General Description EnVentus™ - 0081-5017).

# 2 Type Approvals and Available Hub Heights

The standard turbine is type certified according to the certification standards and available hub heights listed below:

| Certification | Wind Class | Hub Height |
|---|---|---|
| **IECRE OD-501** | IEC S | 105 m, 125 m, 155 m |

# 3 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.

## 3.1 Climate and Site Conditions

The standard turbine is designed for the wind climate conditions listed below. Values refer to hub height.

| **Wind Climate** | **IEC S** | **IEC S** | **IEC S** |
|---|---|---|---|
| **Power Rating** | **6.0 MW** | **6.0 MW** | **6.0 MW** |
| **Hub Height** | **105** | **125** | **155** |
| ***Average design parameters - IEC*** | | | |
| **Wind Speed (10 min average), $V_{ave}$** | 8.5 m/s | 8.5 m/s | 8.0 m/s |
| **Weibull Scale Factor, *C*** | 9.6 m/s | 9.6 m/s | 9.0 m/s |
| **Weibull Shape Factor, *k*** | 2.3 | 2.3 | 2.48 |
| **$I_{ref}$ acc. to IEC 61400-1** | 0.14 | 0.14 | 0.15 |
| **Turbulence Intensity acc. to IEC 61400-1, Including Wind Farm Turbulence (@15 m/s) $I_{90}$ (90% quantile)** | 15.7% | 15.7% | 16.9 % |
| **Wind Shear, *α*** | 0.20 | 0.20 | 0.30 |
| **Inflow Angle (vertical)** | 8° | 8° | 8° |
| ***Extreme design parameters - IEC*** | | | |
| **Extr. Wind Speed (10 min average), $V_{50}$** | 37.5 m/s | 37.5 m/s | 40.1 m/s |
| **Survival Wind Speed (3 s gust), $V_{e50}$** | 52.5 m/s | 52.5 m/s | 56.1 m/s |
| **Turbulence Intensity, $I_{V50}$** | 11 % | 11% | 11 % |

**NOTE** The turbine is intended for low to medium wind speed sites but is also applicable on high wind speed sites, depending on site specific conditions. It is classified as IEC S. Please contact Vestas Wind Systems A/S for further information if needed.

### 3.1.1 Wind Power Plant Layout

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

**NOTE** As evaluation of climate and site conditions is complex, consult Vestas for every project. If conditions exceed the above parameters, Vestas must be consulted.

## 3.2 Operational Envelope – Wind

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

| Wind Climate | IEC S | |
|---|---|---|
| | PO6000 | SO0, SO2, SO3, SO4, SO5, SO6 |
| **Cut-In, $V_{in}$** | 3 m/s | 3 m/s |
| **Cut-Out (10 min exponential avg.), $V_{out}$** | 25 m/s | 20 m/s |
| **Re-Cut In (10 min exponential avg.)** | 23 m/s | 18 m/s |

## 3.3 Operational Envelope – Temperature and Altitude

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

| Operational Envelope – Temperature | |
|---|---|
| **Ambient Temperature Interval** | -20° to +45°C |
| **Ambient Temperature Interval (Low Temperature operation)** | -30° to +45°C |

**NOTE**

The wind turbine will stop producing power at ambient temperatures above 45°C.
For low temperature operation of the wind turbine please consult Vestas.

The turbine is designed for use at altitudes up to 1000 m above sea level as standard and optional up to 2000 m above sea level.

### 3.3.1 Temperature dependent operation

Values below refer to hub height and are determined by the sensors and control system of the turbine. At ambient temperatures above the thresholds shown for each operating mode, the turbine will maintain derated production.

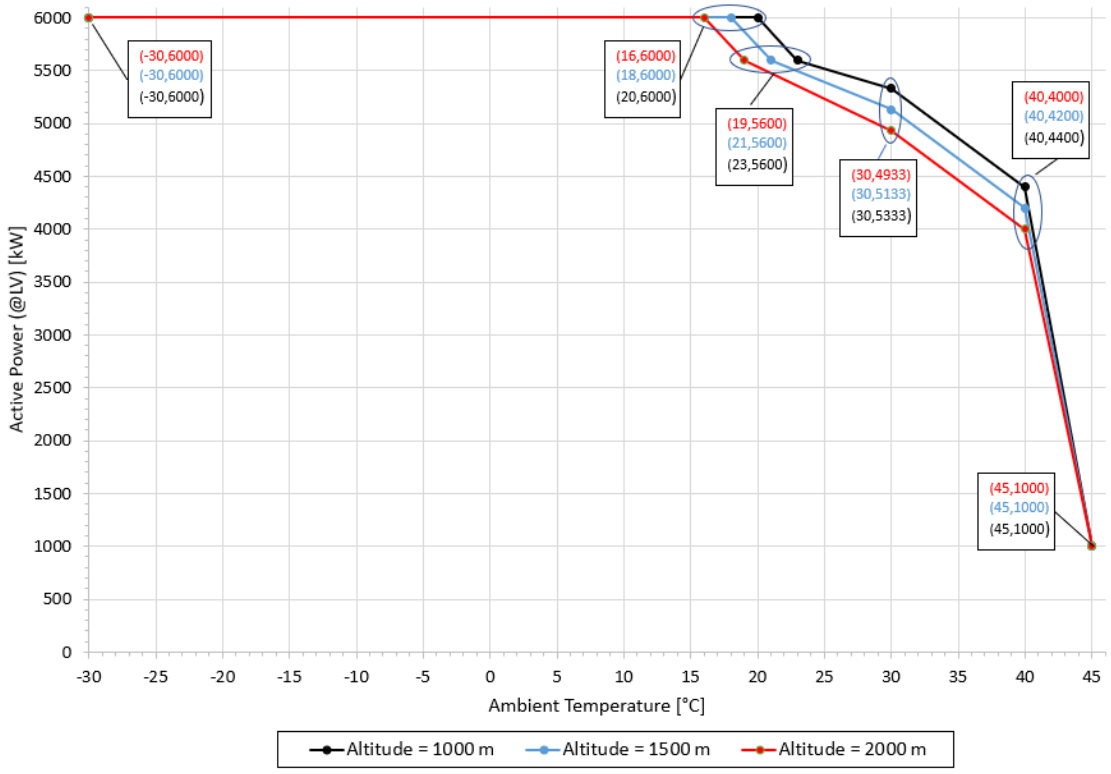



*Figure 3-1: Temperature dependant derated operation*

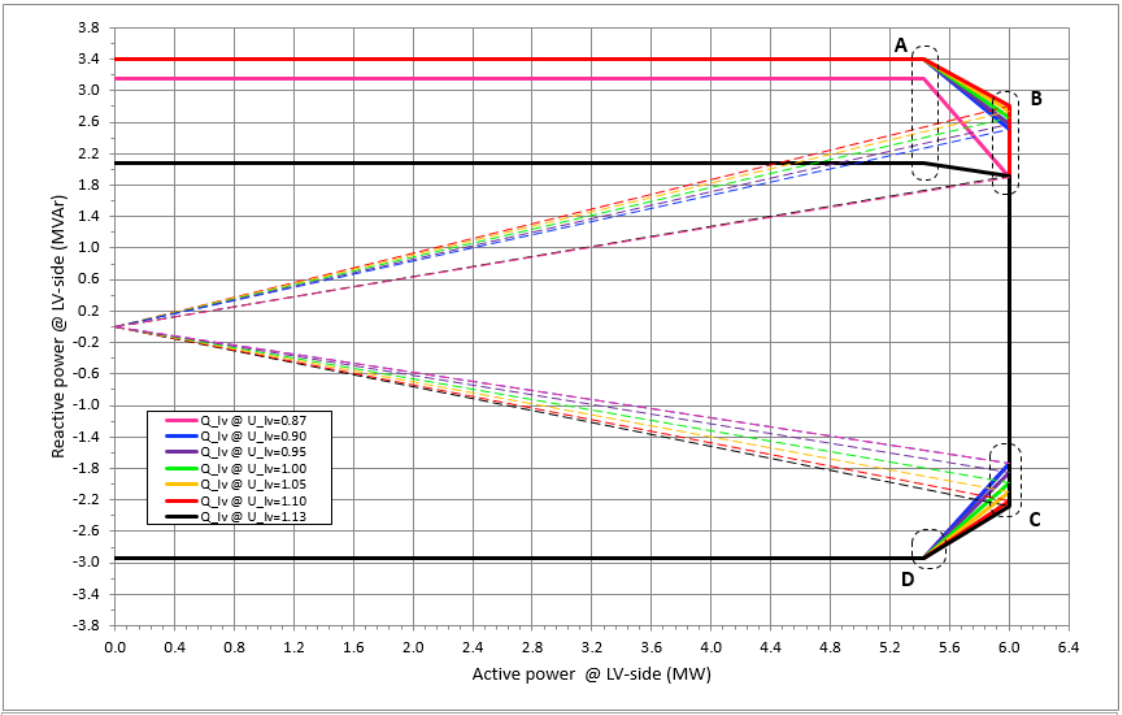
## 3.4 Operational Envelope – Conditions for Power Curve and Ct Values (at Hub Height)

Please consult section 6 and subsequent, for power curves and $C_t$ values.

| Conditions for Power Curve and $C_t$ Values (at Hub Height) | |
|---|---|
| **Wind Shear, *α*** | 0.00-0.30 (10-minute average) |
| **Turbulence Intensity, *I*** | 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° |
| **Grid Voltage** | Nominal Voltage ±2.5% |
| **Grid Frequency** | Nominal Frequency ±0.5 Hz |
| **Grid Active Power (LV-side)** | Per tabulated values in Section 6 and following sections |
| **Grid Reactive Power (LV-side)** | Power Factor 1.0 |

## 3.5 Operational Envelope – Reactive Power Capability

The turbine has a reactive power capability on the low voltage side of the HV transformer as illustrated in Figure 3-2:




| | | Coordinates | | | | | | | | Power factor | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Point: | A | | B | | C | | D | | B (Capacitive) | C (Inductive) |
| | Coordinate: | x (P) | y (Q) | x (P) | y (Q) | x (P) | y (Q) | x (P) | y (Q) | | |
| | Reactive power [kVAr] @ LV side @ U_lv = 0.87 p.u. voltage | 5.430 | 3.160 | 6.000 | 1.900 | 6.000 | -1.739 | 5.430 | -2.933 | 0.953 | 0.960 |
| | Reactive power [kVAr] @ LV side @ U_lv = 0.90 p.u. voltage | 5.430 | 3.400 | 6.000 | 2.503 | 6.000 | -1.739 | 5.430 | -2.933 | 0.923 | 0.960 |
| | Reactive power [kVAr] @ LV side @ U_lv = 0.95 p.u. voltage | 5.430 | 3.400 | 6.000 | 2.584 | 6.000 | -1.856 | 5.430 | -2.933 | 0.918 | 0.955 |
| | Reactive power [kVAr] @ LV side @ U_lv = 1.00 p.u. voltage | 5.430 | 3.400 | 6.000 | 2.664 | 6.000 | -1.987 | 5.430 | -2.933 | 0.914 | 0.949 |
| | Reactive power [kVAr] @ LV side @ U_lv = 1.05 p.u. voltage | 5.430 | 3.400 | 6.000 | 2.736 | 6.000 | -2.093 | 5.430 | -2.933 | 0.910 | 0.944 |
| | Reactive power [kVAr] @ LV side @ U_lv = 1.10 p.u. voltage | 5.430 | 3.400 | 6.000 | 2.807 | 6.000 | -2.213 | 5.430 | -2.933 | 0.906 | 0.938 |
| | Reactive power [kVAr] @ LV side @ U_lv = 1.13 p.u. voltage | 5.430 | 2.080 | 6.000 | 1.919 | 6.000 | -2.283 | 5.430 | -2.933 | 0.952 | 0.935 |

*Figure 3-2: Reactive power capability*

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

## 3.6 Sound Modes

The sound modes listed below are available for the turbine.

| Sound modes | | | |
|---|---|---|---|
| **Mode No.** | **Maximum Sound Level** | **Serrated trailing edges** | **Available hub heights** |
| **PO6000** | 104.9 dBA | Yes (standard) | 105 m, 125 m, 155 m |
| **PO6000-0S** | 107.7 dBA | No (option) | 105 m, 125 m, 155 m |

In addition, Sound Optimized (SO) modes as listed below are available as options for the turbine.

| Sound Optimized (SO) modes | | | |
|---|---|---|---|
| **Mode No.** | **Maximum Sound Level** | **Serrated trailing edges** | **Available hub heights** |
| **SO0** | 104 dBA | Yes (standard) | 105 / 125 / 155 m |
| **SO2** | 102 dBA | Yes (standard) | 105 / 125 / 155 m |
| **SO3** | 101 dBA | Yes (standard) | 105 / 125 / 155 m |
| **SO4** | 100 dBA | Yes (standard) | 105 / 125 / 155 m |
| **SO5** | 99 dBA | Yes (standard) | 105 / 125 / 155 m |
| **SO6** | 98 dBA | Yes (standard) | Site specific |

**NOTE** Sound Optimized (SO) modes are only available with serrated trailing edges on the blades. For further details on sound performance and in case of specific requests, please contact Vestas Wind Systems A/S.

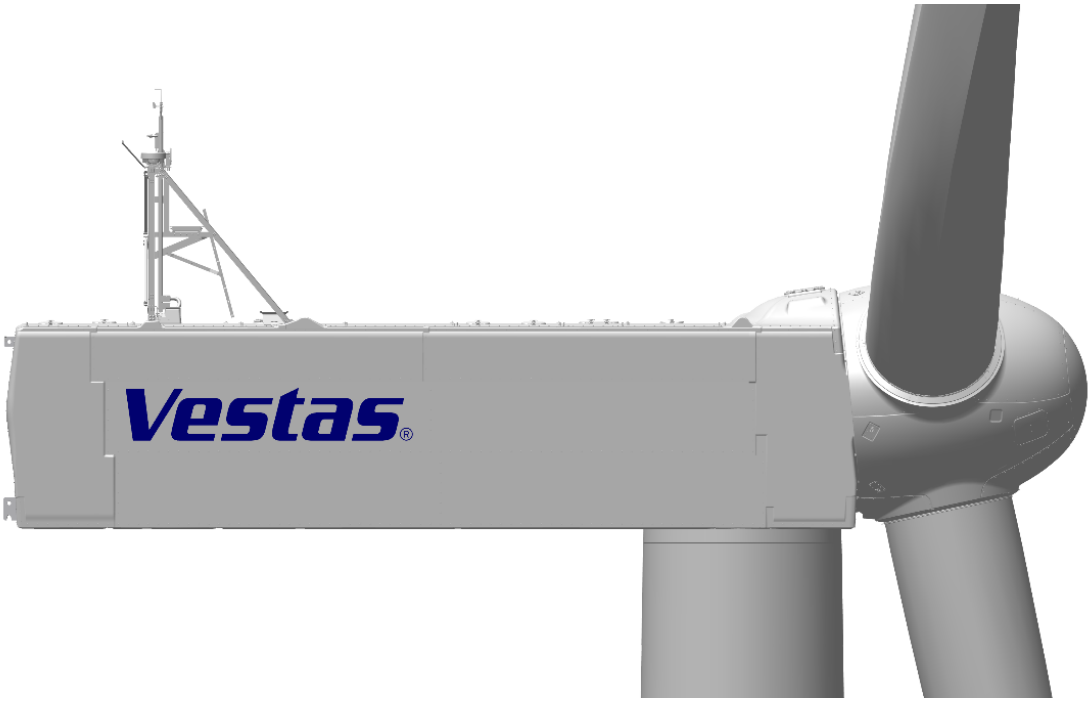
# 4 Drawings

Overview drawings describing the wind turbines, tower and foundation are shown in these documents.

V150 HH105 – 0077-2108
V150 HH125 – 0073-8666
V150 HH155 – 0079-6643

**NOTE** For detailed drawings, please contact Vestas Wind Systems A/S.

## 4.1 Turbine visual impression – side view



## 5 General Reservations, Notes and Disclaimers

- 
- The performance specifications described in this document apply to the current version of the V150-6.0 MW wind turbine. Updated versions of the V150-6.0 MW wind turbine, which may be manufactured in the future, may differ from these performance specifications. In the event that Vestas supplies an updated version of the V150-6.0 MW wind turbine, Vestas will provide an updated performance specification applicable to the updated version.
- All listed start/stop parameters (e.g. wind speeds) 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.
- This document, Performance Specification, is not an offer for sale, and does not contain any guarantee, warranty and/or verification of the power curve and sound (including, without limitation, the power curve and sound verification method). Any guarantee, warranty and/or verification of the power curve and sound (including, without limitation, the power curve and sound verification method) must be agreed to separately in writing.

# 6 Power Curves, Ct Values and Sound Curves, Mode PO6000/PO6000-0S

## 6.1 Power Curves, Mode PO6000/PO6000-0S

| Air density [kg/m$^3$] | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Wind speed [m/s]** | **1.225** | **0.950** | **0.975** | **1.000** | **1.025** | **1.050** | **1.075** | **1.100** | **1.125** | **1.150** | **1.175** | **1.200** | **1.250** | **1.275** |
| **3.0** | **40** | 16 | 17 | 19 | 21 | 22 | 25 | 27 | 29 | 32 | 34 | 37 | 42 | 45 |
| **3.5** | **135** | 85 | 89 | 94 | 99 | 103 | 108 | 112 | 117 | 121 | 126 | 131 | 140 | 144 |
| **4.0** | **250** | 175 | 182 | 189 | 195 | 202 | 209 | 216 | 223 | 230 | 236 | 243 | 257 | 264 |
| **4.5** | **391** | 284 | 294 | 304 | 313 | 323 | 333 | 342 | 352 | 362 | 371 | 381 | 400 | 410 |
| **5.0** | **563** | 419 | 432 | 445 | 458 | 471 | 484 | 498 | 511 | 524 | 537 | 550 | 576 | 589 |
| **5.5** | **775** | 582 | 600 | 617 | 635 | 652 | 670 | 687 | 705 | 722 | 740 | 758 | 793 | 811 |
| **6.0** | **1032** | 779 | 802 | 825 | 848 | 871 | 894 | 917 | 940 | 963 | 986 | 1009 | 1055 | 1078 |
| **6.5** | **1337** | 1015 | 1044 | 1073 | 1102 | 1132 | 1161 | 1190 | 1219 | 1249 | 1278 | 1307 | 1366 | 1395 |
| **7.0** | **1693** | 1291 | 1328 | 1364 | 1401 | 1438 | 1474 | 1511 | 1547 | 1584 | 1620 | 1656 | 1729 | 1766 |
| **7.5** | **2101** | 1609 | 1654 | 1699 | 1744 | 1788 | 1833 | 1878 | 1922 | 1967 | 2012 | 2056 | 2145 | 2190 |
| **8.0** | **2565** | 1970 | 2024 | 2079 | 2133 | 2187 | 2241 | 2295 | 2349 | 2403 | 2457 | 2511 | 2619 | 2672 |
| **8.5** | **3086** | 2377 | 2442 | 2506 | 2571 | 2636 | 2700 | 2765 | 2829 | 2894 | 2958 | 3022 | 3150 | 3214 |
| **9.0** | **3657** | 2825 | 2901 | 2977 | 3054 | 3130 | 3205 | 3281 | 3357 | 3432 | 3507 | 3582 | 3731 | 3805 |
| **9.5** | **4231** | 3304 | 3391 | 3478 | 3565 | 3651 | 3735 | 3819 | 3903 | 3988 | 4069 | 4150 | 4310 | 4388 |
| **10.0** | **4777** | 3796 | 3890 | 3984 | 4078 | 4172 | 4260 | 4349 | 4437 | 4526 | 4610 | 4693 | 4856 | 4935 |
| **10.5** | **5258** | 4270 | 4368 | 4466 | 4563 | 4661 | 4751 | 4840 | 4930 | 5019 | 5099 | 5178 | 5326 | 5395 |
| **11.0** | **5642** | 4717 | 4816 | 4915 | 5015 | 5114 | 5198 | 5282 | 5366 | 5450 | 5514 | 5578 | 5692 | 5741 |
| **11.5** | **5867** | 5127 | 5219 | 5311 | 5403 | 5496 | 5560 | 5623 | 5687 | 5751 | 5790 | 5828 | 5890 | 5913 |
| **12.0** | **5956** | 5479 | 5551 | 5623 | 5695 | 5767 | 5803 | 5839 | 5875 | 5912 | 5926 | 5941 | 5964 | 5973 |
| **12.5** | **5988** | 5736 | 5780 | 5824 | 5868 | 5912 | 5926 | 5941 | 5955 | 5969 | 5976 | 5982 | 5991 | 5995 |
| **13.0** | **5998** | 5890 | 5909 | 5928 | 5948 | 5967 | 5973 | 5980 | 5986 | 5992 | 5994 | 5996 | 5999 | 6000 |
| **13.5** | **6000** | 5949 | 5959 | 5969 | 5979 | 5990 | 5992 | 5994 | 5996 | 5999 | 5999 | 6000 | 6000 | 6000 |
| **14.0** | **6000** | 5982 | 5986 | 5990 | 5994 | 5998 | 5999 | 5999 | 6000 | 6000 | 6000 | 6000 | 6000 | 6000 |
| **14.5** | **6000** | 5995 | 5996 | 5997 | 5998 | 6000 | 6000 | 6000 | 6000 | 6000 | 6000 | 6000 | 6000 | 6000 |
| **15.0** | **6000** | 5999 | 5999 | 5999 | 6000 | 6000 | 6000 | 6000 | 6000 | 6000 | 6000 | 6000 | 6000 | 6000 |
| **15.5** | **6000** | 6000 | 6000 | 6000 | 6000 | 6000 | 6000 | 6000 | 6000 | 6000 | 6000 | 6000 | 6000 | 6000 |
| **16.0** | **6000** | 6000 | 6000 | 6000 | 6000 | 6000 | 6000 | 6000 | 6000 | 6000 | 6000 | 6000 | 6000 | 6000 |
| **16.5** | **6000** | 5998 | 5998 | 5998 | 5998 | 5999 | 5999 | 5999 | 5999 | 5999 | 6000 | 6000 | 6000 | 6000 |
| **17.0** | **5842** | 5780 | 5785 | 5789 | 5794 | 5799 | 5805 | 5811 | 5817 | 5823 | 5829 | 5836 | 5849 | 5856 |
| **17.5** | **5585** | 5525 | 5529 | 5534 | 5539 | 5543 | 5549 | 5554 | 5560 | 5566 | 5572 | 5578 | 5592 | 5599 |
| **18.0** | **5353** | 5295 | 5299 | 5304 | 5308 | 5313 | 5318 | 5324 | 5329 | 5335 | 5341 | 5347 | 5359 | 5366 |
| **18.5** | **5121** | 5062 | 5066 | 5071 | 5076 | 5080 | 5086 | 5091 | 5096 | 5102 | 5108 | 5114 | 5127 | 5133 |
| **19.0** | **4887** | 4832 | 4836 | 4841 | 4845 | 4849 | 4855 | 4860 | 4865 | 4870 | 4876 | 4882 | 4894 | 4900 |
| **19.5** | **4655** | 4603 | 4607 | 4611 | 4616 | 4620 | 4625 | 4630 | 4635 | 4640 | 4645 | 4650 | 4662 | 4668 |
| **20.0** | **4424** | 4375 | 4379 | 4383 | 4387 | 4391 | 4396 | 4400 | 4404 | 4409 | 4414 | 4419 | 4430 | 4435 |
| **20.5** | **4196** | 4151 | 4154 | 4158 | 4161 | 4165 | 4169 | 4173 | 4178 | 4182 | 4187 | 4191 | 4201 | 4205 |
| **21.0** | **3966** | 3922 | 3925 | 3928 | 3932 | 3935 | 3939 | 3944 | 3949 | 3953 | 3957 | 3962 | 3971 | 3975 |
| **21.5** | **3723** | 3687 | 3690 | 3693 | 3696 | 3699 | 3702 | 3705 | 3708 | 3711 | 3715 | 3719 | 3728 | 3733 |
| **22.0** | **3495** | 3468 | 3470 | 3472 | 3474 | 3476 | 3478 | 3481 | 3484 | 3486 | 3489 | 3492 | 3499 | 3503 |
| **22.5** | **3259** | 3231 | 3234 | 3237 | 3239 | 3242 | 3243 | 3245 | 3247 | 3249 | 3252 | 3255 | 3262 | 3265 |
| **23.0** | **3012** | 2991 | 2992 | 2993 | 2995 | 2996 | 2998 | 3000 | 3002 | 3004 | 3006 | 3009 | 3015 | 3018 |
| **23.5** | **2806** | 2789 | 2790 | 2790 | 2791 | 2791 | 2793 | 2796 | 2798 | 2800 | 2802 | 2804 | 2808 | 2809 |
| **24.0** | **2580** | 2561 | 2561 | 2562 | 2563 | 2563 | 2566 | 2568 | 2570 | 2572 | 2575 | 2577 | 2582 | 2584 |
| **24.5** | **2288** | 2266 | 2267 | 2268 | 2269 | 2270 | 2272 | 2274 | 2276 | 2278 | 2281 | 2285 | 2291 | 2295 |
| **25.0** | **2044** | 2006 | 2009 | 2012 | 2015 | 2018 | 2022 | 2025 | 2029 | 2033 | 2036 | 2040 | 2048 | 2052 |

## 6.2 Ct Values, Mode PO6000/PO6000-0S

| Air density kg/m³ | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Wind speed [m/s]** | **1.225** | **0.950** | **0.975** | **1.000** | **1.025** | **1.050** | **1.075** | **1.100** | **1.125** | **1.150** | **1.175** | **1.200** | **1.250** | **1.275** |
| **3.0** | **0.862** | 0.854 | 0.855 | 0.857 | 0.859 | 0.860 | 0.861 | 0.861 | 0.862 | 0.862 | 0.862 | 0.862 | 0.862 | 0.862 |
| **3.5** | **0.840** | 0.840 | 0.840 | 0.840 | 0.840 | 0.840 | 0.840 | 0.840 | 0.840 | 0.840 | 0.840 | 0.840 | 0.840 | 0.840 |
| **4.0** | **0.808** | 0.809 | 0.809 | 0.809 | 0.808 | 0.808 | 0.808 | 0.807 | 0.807 | 0.807 | 0.807 | 0.807 | 0.808 | 0.808 |
| **4.5** | **0.791** | 0.791 | 0.791 | 0.792 | 0.792 | 0.792 | 0.792 | 0.792 | 0.792 | 0.791 | 0.791 | 0.791 | 0.791 | 0.790 |
| **5.0** | **0.784** | 0.789 | 0.788 | 0.788 | 0.787 | 0.787 | 0.787 | 0.786 | 0.786 | 0.785 | 0.785 | 0.784 | 0.783 | 0.783 |
| **5.5** | **0.784** | 0.783 | 0.783 | 0.783 | 0.783 | 0.783 | 0.783 | 0.783 | 0.783 | 0.783 | 0.783 | 0.784 | 0.784 | 0.784 |
| **6.0** | **0.785** | 0.783 | 0.783 | 0.783 | 0.784 | 0.784 | 0.784 | 0.784 | 0.785 | 0.785 | 0.785 | 0.785 | 0.785 | 0.786 |
| **6.5** | **0.786** | 0.785 | 0.785 | 0.785 | 0.785 | 0.785 | 0.786 | 0.786 | 0.786 | 0.786 | 0.786 | 0.786 | 0.786 | 0.786 |
| **7.0** | **0.786** | 0.785 | 0.785 | 0.786 | 0.786 | 0.786 | 0.786 | 0.786 | 0.786 | 0.786 | 0.786 | 0.786 | 0.786 | 0.786 |
| **7.5** | **0.787** | 0.787 | 0.787 | 0.787 | 0.787 | 0.787 | 0.787 | 0.787 | 0.787 | 0.787 | 0.787 | 0.787 | 0.787 | 0.787 |
| **8.0** | **0.787** | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.787 | 0.787 | 0.787 | 0.787 |
| **8.5** | **0.784** | 0.786 | 0.786 | 0.786 | 0.786 | 0.786 | 0.785 | 0.785 | 0.785 | 0.785 | 0.784 | 0.784 | 0.783 | 0.783 |
| **9.0** | **0.769** | 0.775 | 0.775 | 0.774 | 0.774 | 0.774 | 0.773 | 0.773 | 0.772 | 0.772 | 0.771 | 0.770 | 0.768 | 0.767 |
| **9.5** | **0.730** | 0.757 | 0.756 | 0.754 | 0.752 | 0.751 | 0.748 | 0.746 | 0.743 | 0.740 | 0.737 | 0.734 | 0.726 | 0.722 |
| **10.0** | **0.674** | 0.726 | 0.722 | 0.718 | 0.714 | 0.710 | 0.705 | 0.700 | 0.696 | 0.691 | 0.685 | 0.680 | 0.669 | 0.663 |
| **10.5** | **0.613** | 0.679 | 0.674 | 0.668 | 0.662 | 0.657 | 0.651 | 0.645 | 0.638 | 0.632 | 0.626 | 0.619 | 0.606 | 0.598 |
| **11.0** | **0.550** | 0.628 | 0.622 | 0.615 | 0.609 | 0.602 | 0.595 | 0.588 | 0.581 | 0.574 | 0.566 | 0.558 | 0.541 | 0.532 |
| **11.5** | **0.482** | 0.577 | 0.569 | 0.562 | 0.555 | 0.547 | 0.538 | 0.529 | 0.521 | 0.512 | 0.502 | 0.492 | 0.472 | 0.462 |
| **12.0** | **0.417** | 0.527 | 0.517 | 0.508 | 0.499 | 0.490 | 0.479 | 0.469 | 0.459 | 0.448 | 0.438 | 0.428 | 0.408 | 0.398 |
| **12.5** | **0.362** | 0.475 | 0.464 | 0.453 | 0.442 | 0.431 | 0.421 | 0.410 | 0.400 | 0.389 | 0.380 | 0.371 | 0.354 | 0.346 |
| **13.0** | **0.316** | 0.422 | 0.411 | 0.399 | 0.388 | 0.377 | 0.368 | 0.358 | 0.349 | 0.340 | 0.332 | 0.324 | 0.309 | 0.302 |
| **13.5** | **0.279** | 0.372 | 0.362 | 0.352 | 0.342 | 0.332 | 0.323 | 0.315 | 0.307 | 0.299 | 0.292 | 0.285 | 0.273 | 0.267 |
| **14.0** | **0.247** | 0.328 | 0.320 | 0.311 | 0.302 | 0.293 | 0.286 | 0.279 | 0.272 | 0.265 | 0.259 | 0.253 | 0.242 | 0.237 |
| **14.5** | **0.221** | 0.291 | 0.284 | 0.276 | 0.268 | 0.260 | 0.254 | 0.248 | 0.242 | 0.236 | 0.231 | 0.226 | 0.216 | 0.212 |
| **15.0** | **0.198** | 0.260 | 0.253 | 0.246 | 0.239 | 0.233 | 0.227 | 0.222 | 0.217 | 0.211 | 0.207 | 0.202 | 0.194 | 0.190 |
| **15.5** | **0.179** | 0.233 | 0.227 | 0.221 | 0.215 | 0.209 | 0.205 | 0.200 | 0.195 | 0.190 | 0.187 | 0.183 | 0.175 | 0.172 |
| **16.0** | **0.162** | 0.210 | 0.205 | 0.200 | 0.195 | 0.189 | 0.185 | 0.181 | 0.177 | 0.173 | 0.169 | 0.166 | 0.159 | 0.156 |
| **16.5** | **0.147** | 0.191 | 0.186 | 0.181 | 0.177 | 0.172 | 0.168 | 0.164 | 0.161 | 0.157 | 0.154 | 0.151 | 0.145 | 0.142 |
| **17.0** | **0.131** | 0.167 | 0.163 | 0.159 | 0.156 | 0.152 | 0.149 | 0.145 | 0.142 | 0.139 | 0.137 | 0.134 | 0.129 | 0.127 |
| **17.5** | **0.116** | 0.147 | 0.143 | 0.140 | 0.137 | 0.133 | 0.131 | 0.128 | 0.125 | 0.123 | 0.120 | 0.118 | 0.114 | 0.112 |
| **18.0** | **0.102** | 0.129 | 0.126 | 0.123 | 0.120 | 0.117 | 0.115 | 0.113 | 0.110 | 0.108 | 0.106 | 0.104 | 0.100 | 0.098 |
| **18.5** | **0.090** | 0.113 | 0.111 | 0.108 | 0.106 | 0.103 | 0.101 | 0.099 | 0.097 | 0.095 | 0.093 | 0.092 | 0.088 | 0.087 |
| **19.0** | **0.079** | 0.099 | 0.097 | 0.095 | 0.093 | 0.091 | 0.089 | 0.087 | 0.085 | 0.083 | 0.082 | 0.080 | 0.078 | 0.076 |
| **19.5** | **0.070** | 0.088 | 0.086 | 0.084 | 0.082 | 0.080 | 0.078 | 0.077 | 0.075 | 0.074 | 0.072 | 0.071 | 0.069 | 0.068 |
| **20.0** | **0.062** | 0.078 | 0.076 | 0.074 | 0.073 | 0.071 | 0.069 | 0.068 | 0.067 | 0.065 | 0.064 | 0.063 | 0.061 | 0.060 |
| **20.5** | **0.055** | 0.069 | 0.067 | 0.066 | 0.064 | 0.063 | 0.061 | 0.060 | 0.059 | 0.058 | 0.057 | 0.056 | 0.054 | 0.053 |
| **21.0** | **0.049** | 0.061 | 0.059 | 0.058 | 0.057 | 0.055 | 0.054 | 0.053 | 0.052 | 0.051 | 0.050 | 0.049 | 0.048 | 0.047 |
| **21.5** | **0.043** | 0.054 | 0.052 | 0.051 | 0.050 | 0.049 | 0.048 | 0.047 | 0.046 | 0.045 | 0.044 | 0.044 | 0.042 | 0.041 |
| **22.0** | **0.038** | 0.047 | 0.046 | 0.045 | 0.044 | 0.043 | 0.042 | 0.042 | 0.041 | 0.040 | 0.039 | 0.039 | 0.037 | 0.037 |
| **22.5** | **0.033** | 0.042 | 0.041 | 0.040 | 0.039 | 0.038 | 0.037 | 0.037 | 0.036 | 0.035 | 0.034 | 0.034 | 0.033 | 0.032 |
| **23.0** | **0.029** | 0.036 | 0.036 | 0.035 | 0.034 | 0.033 | 0.033 | 0.032 | 0.031 | 0.031 | 0.030 | 0.030 | 0.029 | 0.028 |
| **23.5** | **0.026** | 0.032 | 0.031 | 0.031 | 0.030 | 0.029 | 0.029 | 0.028 | 0.028 | 0.027 | 0.027 | 0.026 | 0.025 | 0.025 |
| **24.0** | **0.022** | 0.028 | 0.027 | 0.027 | 0.026 | 0.026 | 0.025 | 0.025 | 0.024 | 0.024 | 0.023 | 0.023 | 0.022 | 0.022 |
| **24.5** | **0.019** | 0.024 | 0.023 | 0.023 | 0.022 | 0.022 | 0.021 | 0.021 | 0.020 | 0.020 | 0.020 | 0.019 | 0.019 | 0.018 |
| **25.0** | **0.016** | 0.020 | 0.020 | 0.019 | 0.019 | 0.018 | 0.018 | 0.018 | 0.017 | 0.017 | 0.017 | 0.017 | 0.016 | 0.016 |

## 6.3 Sound Curves, Mode PO6000/PO6000-0S

| Sound Power Level at Hub Height | | |
|---|---|---|
| **Conditions for Sound Power Level:** | **Measurement standard IEC 61400-11 ed. 3**<br>**Maximum turbulence at hub height: 30%**<br>**Inflow angle (vertical): 0 ±2°**<br>**Air density: 1.225 kg/m$^3$** | |
| **Wind speed at hub height [m/s]** | **Sound Power Level at Hub Height [dBA] Mode PO6000 (Blades with serrated trailing edge)** | **Sound Power Level at Hub Height [dBA] Mode PO6000-0S (Blades without serrated trailing edge)** |
| 3 | 92.0 | 94.8 |
| 4 | 92.2 | 95.0 |
| 5 | 94.0 | 96.8 |
| 6 | 96.9 | 99.7 |
| 7 | 99.9 | 102.7 |
| 8 | 102.7 | 105.5 |
| 9 | 104.6 | 107.4 |
| 10 | 104.8 | 107.6 |
| 11 | 104.9 | 107.7 |
| 12 | 104.9 | 107.7 |
| 13 | 104.9 | 107.7 |
| 14 | 104.9 | 107.7 |
| 15 | 104.9 | 107.7 |
| 16 | 104.9 | 107.7 |
| 17 | 104.9 | 107.7 |
| 18 | 104.9 | 107.7 |
| 19 | 104.9 | 107.7 |
| 20 | 104.9 | 107.7 |

# 7 Power Curves, Ct Values and Sound Curves, Sound Optimized Modes

## 7.1 Power Curves, Sound Optimized Mode SO0

| Air density [kg/m³] | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Wind speed [m/s]** | **1.225** | **0.950** | **0.975** | **1.000** | **1.025** | **1.050** | **1.075** | **1.100** | **1.125** | **1.150** | **1.175** | **1.200** | **1.250** | **1.275** |
| **3.0** | **40** | 13 | 15 | 17 | 19 | 22 | 24 | 27 | 29 | 32 | 35 | 38 | 43 | 46 |
| **3.5** | **137** | 86 | 91 | 95 | 100 | 105 | 109 | 114 | 118 | 123 | 128 | 132 | 141 | 146 |
| **4.0** | **251** | 175 | 182 | 189 | 196 | 203 | 210 | 217 | 223 | 230 | 237 | 244 | 258 | 264 |
| **4.5** | **391** | 284 | 294 | 304 | 313 | 323 | 333 | 342 | 352 | 362 | 371 | 381 | 401 | 410 |
| **5.0** | **564** | 419 | 432 | 445 | 459 | 472 | 485 | 498 | 511 | 524 | 538 | 551 | 577 | 590 |
| **5.5** | **777** | 583 | 600 | 618 | 635 | 653 | 671 | 688 | 706 | 724 | 741 | 759 | 794 | 812 |
| **6.0** | **1034** | 780 | 803 | 826 | 850 | 873 | 896 | 919 | 942 | 965 | 988 | 1011 | 1057 | 1080 |
| **6.5** | **1339** | 1016 | 1045 | 1075 | 1104 | 1134 | 1163 | 1192 | 1222 | 1251 | 1280 | 1310 | 1368 | 1398 |
| **7.0** | **1696** | 1293 | 1330 | 1367 | 1403 | 1440 | 1477 | 1513 | 1550 | 1587 | 1623 | 1660 | 1733 | 1769 |
| **7.5** | **2105** | 1612 | 1657 | 1702 | 1747 | 1792 | 1836 | 1881 | 1926 | 1971 | 2015 | 2060 | 2149 | 2194 |
| **8.0** | **2568** | 1973 | 2028 | 2082 | 2136 | 2190 | 2244 | 2298 | 2352 | 2406 | 2460 | 2514 | 2622 | 2675 |
| **8.5** | **3087** | 2378 | 2443 | 2508 | 2572 | 2637 | 2702 | 2766 | 2831 | 2895 | 2959 | 3023 | 3151 | 3215 |
| **9.0** | **3653** | 2822 | 2898 | 2974 | 3050 | 3126 | 3202 | 3278 | 3353 | 3429 | 3504 | 3578 | 3727 | 3801 |
| **9.5** | **4222** | 3288 | 3376 | 3463 | 3551 | 3638 | 3723 | 3808 | 3893 | 3978 | 4060 | 4141 | 4301 | 4379 |
| **10.0** | **4748** | 3748 | 3846 | 3944 | 4042 | 4140 | 4231 | 4322 | 4413 | 4504 | 4585 | 4667 | 4820 | 4893 |
| **10.5** | **5154** | 4176 | 4283 | 4389 | 4495 | 4601 | 4689 | 4777 | 4864 | 4952 | 5020 | 5087 | 5208 | 5261 |
| **11.0** | **5429** | 4559 | 4666 | 4773 | 4880 | 4987 | 5062 | 5138 | 5213 | 5288 | 5335 | 5382 | 5459 | 5489 |
| **11.5** | **5541** | 4884 | 4978 | 5073 | 5168 | 5263 | 5315 | 5368 | 5421 | 5473 | 5496 | 5519 | 5552 | 5564 |
| **12.0** | **5578** | 5125 | 5202 | 5278 | 5354 | 5431 | 5460 | 5490 | 5519 | 5548 | 5558 | 5568 | 5584 | 5590 |
| **12.5** | **5593** | 5301 | 5355 | 5408 | 5461 | 5515 | 5530 | 5545 | 5560 | 5576 | 5581 | 5587 | 5596 | 5598 |
| **13.0** | **5598** | 5414 | 5448 | 5483 | 5518 | 5552 | 5561 | 5570 | 5579 | 5588 | 5592 | 5595 | 5599 | 5600 |
| **13.5** | **5599** | 5460 | 5487 | 5515 | 5542 | 5569 | 5576 | 5583 | 5590 | 5596 | 5597 | 5598 | 5600 | 5600 |
| **14.0** | **5600** | 5493 | 5515 | 5536 | 5558 | 5579 | 5584 | 5589 | 5593 | 5598 | 5599 | 5599 | 5600 | 5600 |
| **14.5** | **5600** | 5515 | 5532 | 5550 | 5567 | 5584 | 5588 | 5592 | 5595 | 5599 | 5599 | 5599 | 5600 | 5600 |
| **15.0** | **5600** | 5526 | 5541 | 5556 | 5571 | 5586 | 5589 | 5592 | 5595 | 5598 | 5598 | 5599 | 5600 | 5600 |
| **15.5** | **5600** | 5539 | 5551 | 5564 | 5577 | 5589 | 5591 | 5594 | 5596 | 5598 | 5599 | 5599 | 5600 | 5600 |
| **16.0** | **5600** | 5549 | 5559 | 5570 | 5581 | 5591 | 5593 | 5595 | 5597 | 5599 | 5599 | 5599 | 5600 | 5600 |
| **16.5** | **5600** | 5557 | 5566 | 5575 | 5584 | 5593 | 5595 | 5596 | 5597 | 5599 | 5599 | 5599 | 5600 | 5600 |
| **17.0** | **5597** | 5554 | 5563 | 5572 | 5580 | 5589 | 5591 | 5592 | 5594 | 5596 | 5596 | 5597 | 5598 | 5598 |
| **17.5** | **5563** | 5487 | 5499 | 5511 | 5523 | 5535 | 5539 | 5544 | 5548 | 5553 | 5556 | 5559 | 5565 | 5568 |
| **18.0** | **5433** | 5312 | 5328 | 5345 | 5362 | 5378 | 5387 | 5396 | 5404 | 5413 | 5420 | 5426 | 5440 | 5446 |
| **18.5** | **5233** | 5070 | 5092 | 5114 | 5136 | 5158 | 5170 | 5182 | 5193 | 5205 | 5215 | 5224 | 5242 | 5250 |
| **19.0** | **5006** | 4806 | 4833 | 4860 | 4887 | 4914 | 4928 | 4942 | 4957 | 4972 | 4983 | 4994 | 5016 | 5026 |
| **19.5** | **4773** | 4554 | 4583 | 4612 | 4642 | 4671 | 4688 | 4705 | 4722 | 4739 | 4750 | 4762 | 4783 | 4793 |
| **20.0** | **4544** | 4319 | 4349 | 4379 | 4409 | 4439 | 4456 | 4474 | 4491 | 4509 | 4520 | 4532 | 4553 | 4563 |

## 7.2 Ct Values, Sound Optimized Mode SO0

| Air density kg/m³ | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Wind speed [m/s]** | **1.225** | **0.950** | **0.975** | **1.000** | **1.025** | **1.050** | **1.075** | **1.100** | **1.125** | **1.150** | **1.175** | **1.200** | **1.250** | **1.275** |
| **3.0** | **0.877** | 0.869 | 0.870 | 0.872 | 0.874 | 0.875 | 0.876 | 0.876 | 0.876 | 0.877 | 0.877 | 0.877 | 0.877 | 0.877 |
| **3.5** | **0.838** | 0.838 | 0.838 | 0.838 | 0.838 | 0.838 | 0.838 | 0.838 | 0.838 | 0.838 | 0.838 | 0.838 | 0.838 | 0.838 |
| **4.0** | **0.800** | 0.800 | 0.800 | 0.800 | 0.800 | 0.800 | 0.800 | 0.800 | 0.800 | 0.800 | 0.800 | 0.800 | 0.800 | 0.800 |
| **4.5** | **0.790** | 0.789 | 0.790 | 0.790 | 0.790 | 0.791 | 0.790 | 0.790 | 0.790 | 0.790 | 0.790 | 0.790 | 0.790 | 0.789 |
| **5.0** | **0.784** | 0.788 | 0.788 | 0.787 | 0.787 | 0.786 | 0.786 | 0.786 | 0.785 | 0.785 | 0.785 | 0.784 | 0.784 | 0.783 |
| **5.5** | **0.785** | 0.783 | 0.783 | 0.783 | 0.783 | 0.783 | 0.783 | 0.784 | 0.784 | 0.784 | 0.784 | 0.784 | 0.785 | 0.785 |
| **6.0** | **0.787** | 0.784 | 0.784 | 0.784 | 0.785 | 0.785 | 0.785 | 0.786 | 0.786 | 0.786 | 0.787 | 0.787 | 0.788 | 0.788 |
| **6.5** | **0.790** | 0.786 | 0.787 | 0.787 | 0.787 | 0.788 | 0.788 | 0.788 | 0.789 | 0.789 | 0.789 | 0.789 | 0.790 | 0.790 |
| **7.0** | **0.793** | 0.788 | 0.789 | 0.789 | 0.790 | 0.790 | 0.791 | 0.791 | 0.792 | 0.792 | 0.792 | 0.793 | 0.793 | 0.794 |
| **7.5** | **0.798** | 0.795 | 0.795 | 0.795 | 0.796 | 0.796 | 0.796 | 0.797 | 0.797 | 0.797 | 0.797 | 0.798 | 0.798 | 0.799 |
| **8.0** | **0.798** | 0.794 | 0.795 | 0.795 | 0.796 | 0.796 | 0.797 | 0.797 | 0.797 | 0.797 | 0.798 | 0.798 | 0.798 | 0.799 |
| **8.5** | **0.788** | 0.785 | 0.785 | 0.785 | 0.785 | 0.786 | 0.786 | 0.786 | 0.787 | 0.787 | 0.787 | 0.787 | 0.788 | 0.788 |
| **9.0** | **0.774** | 0.773 | 0.773 | 0.773 | 0.773 | 0.774 | 0.774 | 0.774 | 0.774 | 0.774 | 0.774 | 0.774 | 0.773 | 0.772 |
| **9.5** | **0.739** | 0.755 | 0.754 | 0.754 | 0.754 | 0.753 | 0.752 | 0.750 | 0.749 | 0.747 | 0.744 | 0.741 | 0.735 | 0.731 |
| **10.0** | **0.682** | 0.720 | 0.719 | 0.717 | 0.715 | 0.714 | 0.710 | 0.706 | 0.702 | 0.699 | 0.693 | 0.687 | 0.675 | 0.668 |
| **10.5** | **0.610** | 0.671 | 0.668 | 0.665 | 0.663 | 0.660 | 0.654 | 0.647 | 0.641 | 0.635 | 0.627 | 0.618 | 0.601 | 0.591 |
| **11.0** | **0.534** | 0.615 | 0.611 | 0.607 | 0.602 | 0.598 | 0.590 | 0.582 | 0.574 | 0.566 | 0.555 | 0.545 | 0.524 | 0.513 |
| **11.5** | **0.457** | 0.552 | 0.546 | 0.541 | 0.535 | 0.529 | 0.520 | 0.510 | 0.500 | 0.491 | 0.480 | 0.469 | 0.447 | 0.436 |
| **12.0** | **0.392** | 0.490 | 0.483 | 0.477 | 0.470 | 0.463 | 0.452 | 0.442 | 0.432 | 0.422 | 0.412 | 0.402 | 0.383 | 0.374 |
| **12.5** | **0.340** | 0.435 | 0.427 | 0.419 | 0.411 | 0.402 | 0.393 | 0.383 | 0.374 | 0.364 | 0.356 | 0.348 | 0.332 | 0.325 |
| **13.0** | **0.297** | 0.385 | 0.377 | 0.368 | 0.360 | 0.351 | 0.343 | 0.335 | 0.327 | 0.318 | 0.311 | 0.304 | 0.291 | 0.284 |
| **13.5** | **0.262** | 0.340 | 0.332 | 0.325 | 0.317 | 0.310 | 0.302 | 0.295 | 0.288 | 0.281 | 0.275 | 0.268 | 0.257 | 0.251 |
| **14.0** | **0.233** | 0.302 | 0.295 | 0.288 | 0.281 | 0.274 | 0.268 | 0.262 | 0.256 | 0.249 | 0.244 | 0.238 | 0.228 | 0.223 |
| **14.5** | **0.208** | 0.269 | 0.263 | 0.257 | 0.251 | 0.245 | 0.239 | 0.234 | 0.228 | 0.223 | 0.218 | 0.213 | 0.204 | 0.200 |
| **15.0** | **0.187** | 0.241 | 0.236 | 0.230 | 0.225 | 0.219 | 0.214 | 0.210 | 0.205 | 0.200 | 0.196 | 0.192 | 0.184 | 0.180 |
| **15.5** | **0.169** | 0.218 | 0.213 | 0.208 | 0.203 | 0.198 | 0.194 | 0.189 | 0.185 | 0.180 | 0.177 | 0.173 | 0.166 | 0.163 |
| **16.0** | **0.154** | 0.197 | 0.193 | 0.188 | 0.184 | 0.179 | 0.175 | 0.171 | 0.168 | 0.164 | 0.160 | 0.157 | 0.151 | 0.148 |
| **16.5** | **0.140** | 0.179 | 0.175 | 0.171 | 0.167 | 0.163 | 0.160 | 0.156 | 0.153 | 0.149 | 0.146 | 0.143 | 0.137 | 0.135 |
| **17.0** | **0.128** | 0.164 | 0.160 | 0.156 | 0.153 | 0.149 | 0.146 | 0.143 | 0.139 | 0.136 | 0.134 | 0.131 | 0.126 | 0.123 |
| **17.5** | **0.118** | 0.149 | 0.145 | 0.142 | 0.139 | 0.136 | 0.133 | 0.130 | 0.127 | 0.125 | 0.122 | 0.120 | 0.115 | 0.113 |
| **18.0** | **0.106** | 0.132 | 0.129 | 0.127 | 0.124 | 0.121 | 0.119 | 0.117 | 0.114 | 0.112 | 0.110 | 0.108 | 0.104 | 0.102 |
| **18.5** | **0.094** | 0.116 | 0.114 | 0.112 | 0.110 | 0.107 | 0.105 | 0.103 | 0.101 | 0.099 | 0.098 | 0.096 | 0.093 | 0.091 |
| **19.0** | **0.083** | 0.101 | 0.100 | 0.098 | 0.096 | 0.094 | 0.093 | 0.091 | 0.089 | 0.088 | 0.086 | 0.085 | 0.082 | 0.081 |
| **19.5** | **0.074** | 0.089 | 0.088 | 0.086 | 0.085 | 0.083 | 0.082 | 0.081 | 0.079 | 0.078 | 0.076 | 0.075 | 0.073 | 0.072 |
| **20.0** | **0.066** | 0.079 | 0.078 | 0.076 | 0.075 | 0.074 | 0.073 | 0.071 | 0.070 | 0.069 | 0.068 | 0.067 | 0.065 | 0.064 |

## 7.3 Sound Curves, Sound Optimized Mode SO0

| Sound Power Level at Hub Height | |
|---|---|
| **Conditions for Sound Power Level:** | **Measurement standard IEC 61400-11 ed. 3**<br>**Maximum turbulence at hub height: 30%**<br>**Inflow angle (vertical): 0 ±2°**<br>**Air density: 1.225 kg/m$^3$** |
| **Wind speed at hub height [m/s]** | **Sound Power Level at Hub Height [dBA]**<br>**Sound Optimized ModeSO0 (Blades with serrated trailing edge)** |
| 3 | 91.3 |
| 4 | 91.8 |
| 5 | 94.1 |
| 6 | 96.9 |
| 7 | 100.0 |
| 8 | 102.6 |
| 9 | 103.7 |
| 10 | 103.9 |
| 11 | 104.0 |
| 12 | 104.0 |
| 13 | 104.0 |
| 14 | 104.0 |
| 15 | 104.0 |
| 16 | 104.0 |
| 17 | 104.0 |
| 18 | 104.0 |
| 19 | 104.0 |
| 20 | 104.0 |

## 7.4 Power Curves, Sound Optimized Mode SO2

| Air density [kg/m³] | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Wind speed [m/s]** | **1.225** | **0.950** | **0.975** | **1.000** | **1.025** | **1.050** | **1.075** | **1.100** | **1.125** | **1.150** | **1.175** | **1.200** | **1.250** | **1.275** |
| **3.0** | **42** | 13 | 16 | 18 | 20 | 23 | 25 | 28 | 31 | 33 | 36 | 39 | 45 | 48 |
| **3.5** | **138** | 87 | 92 | 97 | 101 | 106 | 111 | 115 | 120 | 124 | 129 | 134 | 143 | 147 |
| **4.0** | **252** | 177 | 184 | 191 | 197 | 204 | 211 | 218 | 225 | 232 | 239 | 246 | 259 | 266 |
| **4.5** | **393** | 286 | 295 | 305 | 315 | 325 | 334 | 344 | 354 | 364 | 373 | 383 | 403 | 412 |
| **5.0** | **567** | 421 | 434 | 448 | 461 | 474 | 487 | 501 | 514 | 527 | 540 | 553 | 580 | 593 |
| **5.5** | **780** | 586 | 603 | 621 | 639 | 656 | 674 | 692 | 709 | 727 | 745 | 763 | 798 | 816 |
| **6.0** | **1039** | 784 | 807 | 831 | 854 | 877 | 900 | 923 | 946 | 970 | 993 | 1016 | 1062 | 1085 |
| **6.5** | **1345** | 1021 | 1051 | 1080 | 1110 | 1139 | 1169 | 1198 | 1228 | 1257 | 1287 | 1316 | 1375 | 1404 |
| **7.0** | **1705** | 1300 | 1337 | 1374 | 1411 | 1448 | 1484 | 1521 | 1558 | 1595 | 1631 | 1668 | 1741 | 1778 |
| **7.5** | **2112** | 1618 | 1663 | 1708 | 1753 | 1798 | 1843 | 1888 | 1933 | 1978 | 2022 | 2067 | 2157 | 2202 |
| **8.0** | **2570** | 1974 | 2029 | 2083 | 2137 | 2192 | 2246 | 2300 | 2354 | 2408 | 2462 | 2516 | 2624 | 2678 |
| **8.5** | **3042** | 2342 | 2405 | 2469 | 2533 | 2597 | 2661 | 2724 | 2788 | 2852 | 2915 | 2979 | 3105 | 3168 |
| **9.0** | **3565** | 2750 | 2824 | 2898 | 2973 | 3047 | 3121 | 3196 | 3270 | 3344 | 3418 | 3491 | 3637 | 3710 |
| **9.5** | **4097** | 3176 | 3262 | 3347 | 3432 | 3517 | 3601 | 3685 | 3770 | 3854 | 3935 | 4016 | 4169 | 4241 |
| **10.0** | **4513** | 3566 | 3661 | 3756 | 3851 | 3946 | 4034 | 4123 | 4212 | 4300 | 4371 | 4442 | 4570 | 4626 |
| **10.5** | **4761** | 3910 | 4009 | 4109 | 4208 | 4307 | 4384 | 4461 | 4538 | 4615 | 4664 | 4712 | 4793 | 4824 |
| **11.0** | **4892** | 4210 | 4302 | 4393 | 4485 | 4576 | 4635 | 4694 | 4752 | 4811 | 4838 | 4865 | 4904 | 4917 |
| **11.5** | **4924** | 4434 | 4512 | 4590 | 4668 | 4746 | 4782 | 4818 | 4854 | 4890 | 4901 | 4913 | 4931 | 4937 |
| **12.0** | **4940** | 4602 | 4662 | 4722 | 4781 | 4841 | 4860 | 4880 | 4899 | 4919 | 4926 | 4933 | 4943 | 4947 |
| **12.5** | **4947** | 4711 | 4754 | 4798 | 4842 | 4886 | 4897 | 4909 | 4921 | 4933 | 4938 | 4942 | 4948 | 4950 |
| **13.0** | **4949** | 4773 | 4806 | 4839 | 4872 | 4905 | 4914 | 4922 | 4931 | 4940 | 4943 | 4946 | 4950 | 4951 |
| **13.5** | **4950** | 4799 | 4828 | 4857 | 4886 | 4915 | 4923 | 4930 | 4938 | 4946 | 4947 | 4949 | 4950 | 4951 |
| **14.0** | **4950** | 4826 | 4850 | 4874 | 4899 | 4923 | 4929 | 4935 | 4941 | 4947 | 4948 | 4949 | 4951 | 4951 |
| **14.5** | **4950** | 4847 | 4867 | 4888 | 4908 | 4928 | 4933 | 4938 | 4943 | 4948 | 4949 | 4950 | 4951 | 4951 |
| **15.0** | **4950** | 4863 | 4880 | 4896 | 4913 | 4930 | 4934 | 4939 | 4943 | 4948 | 4949 | 4949 | 4950 | 4951 |
| **15.5** | **4950** | 4877 | 4891 | 4906 | 4920 | 4934 | 4938 | 4941 | 4945 | 4948 | 4949 | 4950 | 4951 | 4951 |
| **16.0** | **4950** | 4884 | 4897 | 4910 | 4924 | 4937 | 4940 | 4943 | 4946 | 4949 | 4949 | 4950 | 4951 | 4951 |
| **16.5** | **4951** | 4885 | 4898 | 4912 | 4925 | 4938 | 4941 | 4943 | 4946 | 4949 | 4950 | 4950 | 4951 | 4951 |
| **17.0** | **4950** | 4884 | 4897 | 4910 | 4924 | 4937 | 4940 | 4943 | 4946 | 4949 | 4949 | 4950 | 4951 | 4951 |
| **17.5** | **4951** | 4864 | 4881 | 4898 | 4914 | 4931 | 4935 | 4940 | 4944 | 4948 | 4949 | 4950 | 4951 | 4951 |
| **18.0** | **4950** | 4863 | 4880 | 4896 | 4913 | 4930 | 4935 | 4939 | 4943 | 4948 | 4948 | 4949 | 4951 | 4951 |
| **18.5** | **4946** | 4842 | 4860 | 4879 | 4898 | 4916 | 4922 | 4928 | 4934 | 4940 | 4942 | 4944 | 4947 | 4948 |
| **19.0** | **4885** | 4722 | 4746 | 4770 | 4794 | 4818 | 4830 | 4842 | 4854 | 4866 | 4872 | 4878 | 4889 | 4894 |
| **19.5** | **4740** | 4531 | 4560 | 4588 | 4617 | 4645 | 4661 | 4677 | 4693 | 4709 | 4719 | 4730 | 4748 | 4755 |
| **20.0** | **4532** | 4306 | 4336 | 4365 | 4395 | 4425 | 4443 | 4461 | 4479 | 4498 | 4509 | 4520 | 4542 | 4551 |

## 7.5 Ct Values, Sound Optimized Mode SO2

| Air density kg/m³ | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Wind speed [m/s]** | **1.225** | **0.950** | **0.975** | **1.000** | **1.025** | **1.050** | **1.075** | **1.100** | **1.125** | **1.150** | **1.175** | **1.200** | **1.250** | **1.275** |
| **3.0** | **0.885** | 0.877 | 0.878 | 0.880 | 0.881 | 0.883 | 0.883 | 0.884 | 0.884 | 0.884 | 0.884 | 0.884 | 0.884 | 0.884 |
| **3.5** | **0.844** | 0.844 | 0.844 | 0.844 | 0.844 | 0.844 | 0.844 | 0.844 | 0.844 | 0.844 | 0.844 | 0.844 | 0.844 | 0.844 |
| **4.0** | **0.806** | 0.805 | 0.805 | 0.805 | 0.805 | 0.805 | 0.805 | 0.805 | 0.806 | 0.806 | 0.806 | 0.806 | 0.805 | 0.805 |
| **4.5** | **0.795** | 0.795 | 0.795 | 0.795 | 0.796 | 0.796 | 0.796 | 0.796 | 0.796 | 0.796 | 0.795 | 0.795 | 0.795 | 0.795 |
| **5.0** | **0.789** | 0.793 | 0.793 | 0.792 | 0.792 | 0.792 | 0.791 | 0.791 | 0.791 | 0.790 | 0.790 | 0.790 | 0.789 | 0.789 |
| **5.5** | **0.790** | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.789 | 0.789 | 0.789 | 0.789 | 0.789 | 0.790 | 0.790 | 0.790 |
| **6.0** | **0.792** | 0.789 | 0.789 | 0.790 | 0.790 | 0.790 | 0.791 | 0.791 | 0.791 | 0.792 | 0.792 | 0.792 | 0.793 | 0.793 |
| **6.5** | **0.796** | 0.792 | 0.793 | 0.793 | 0.793 | 0.794 | 0.794 | 0.794 | 0.795 | 0.795 | 0.795 | 0.795 | 0.796 | 0.796 |
| **7.0** | **0.798** | 0.795 | 0.795 | 0.795 | 0.796 | 0.796 | 0.796 | 0.797 | 0.797 | 0.797 | 0.798 | 0.798 | 0.798 | 0.799 |
| **7.5** | **0.797** | 0.792 | 0.793 | 0.793 | 0.793 | 0.794 | 0.794 | 0.795 | 0.795 | 0.795 | 0.796 | 0.796 | 0.797 | 0.797 |
| **8.0** | **0.778** | 0.775 | 0.776 | 0.776 | 0.776 | 0.776 | 0.776 | 0.777 | 0.777 | 0.777 | 0.777 | 0.777 | 0.778 | 0.779 |
| **8.5** | **0.733** | 0.731 | 0.731 | 0.731 | 0.731 | 0.731 | 0.732 | 0.732 | 0.732 | 0.732 | 0.732 | 0.733 | 0.733 | 0.733 |
| **9.0** | **0.709** | 0.707 | 0.707 | 0.707 | 0.707 | 0.708 | 0.708 | 0.708 | 0.709 | 0.709 | 0.709 | 0.709 | 0.709 | 0.709 |
| **9.5** | **0.690** | 0.695 | 0.696 | 0.696 | 0.696 | 0.696 | 0.696 | 0.696 | 0.696 | 0.695 | 0.694 | 0.692 | 0.686 | 0.682 |
| **10.0** | **0.630** | 0.657 | 0.657 | 0.657 | 0.657 | 0.658 | 0.655 | 0.653 | 0.650 | 0.648 | 0.642 | 0.636 | 0.622 | 0.613 |
| **10.5** | **0.545** | 0.599 | 0.598 | 0.597 | 0.596 | 0.595 | 0.590 | 0.585 | 0.579 | 0.574 | 0.564 | 0.555 | 0.534 | 0.523 |
| **11.0** | **0.462** | 0.539 | 0.536 | 0.532 | 0.529 | 0.525 | 0.517 | 0.510 | 0.502 | 0.494 | 0.484 | 0.473 | 0.451 | 0.441 |
| **11.5** | **0.392** | 0.477 | 0.472 | 0.467 | 0.462 | 0.457 | 0.448 | 0.439 | 0.430 | 0.421 | 0.411 | 0.401 | 0.383 | 0.374 |
| **12.0** | **0.337** | 0.423 | 0.416 | 0.410 | 0.403 | 0.397 | 0.388 | 0.379 | 0.370 | 0.362 | 0.353 | 0.345 | 0.330 | 0.322 |
| **12.5** | **0.294** | 0.374 | 0.367 | 0.360 | 0.353 | 0.346 | 0.338 | 0.330 | 0.322 | 0.314 | 0.307 | 0.300 | 0.287 | 0.281 |
| **13.0** | **0.258** | 0.330 | 0.323 | 0.316 | 0.310 | 0.303 | 0.296 | 0.289 | 0.283 | 0.276 | 0.270 | 0.264 | 0.252 | 0.247 |
| **13.5** | **0.228** | 0.292 | 0.286 | 0.280 | 0.274 | 0.268 | 0.262 | 0.256 | 0.250 | 0.244 | 0.239 | 0.234 | 0.224 | 0.219 |
| **14.0** | **0.203** | 0.260 | 0.254 | 0.249 | 0.244 | 0.238 | 0.233 | 0.228 | 0.222 | 0.217 | 0.213 | 0.208 | 0.199 | 0.195 |
| **14.5** | **0.182** | 0.233 | 0.228 | 0.223 | 0.218 | 0.213 | 0.208 | 0.204 | 0.199 | 0.194 | 0.190 | 0.186 | 0.179 | 0.175 |
| **15.0** | **0.164** | 0.210 | 0.205 | 0.201 | 0.196 | 0.191 | 0.187 | 0.183 | 0.179 | 0.175 | 0.171 | 0.168 | 0.161 | 0.158 |
| **15.5** | **0.149** | 0.190 | 0.185 | 0.181 | 0.177 | 0.173 | 0.169 | 0.166 | 0.162 | 0.158 | 0.155 | 0.152 | 0.146 | 0.143 |
| **16.0** | **0.135** | 0.172 | 0.168 | 0.164 | 0.161 | 0.157 | 0.154 | 0.150 | 0.147 | 0.144 | 0.141 | 0.138 | 0.133 | 0.130 |
| **16.5** | **0.123** | 0.156 | 0.153 | 0.150 | 0.146 | 0.143 | 0.140 | 0.137 | 0.134 | 0.131 | 0.128 | 0.126 | 0.121 | 0.119 |
| **17.0** | **0.113** | 0.143 | 0.140 | 0.137 | 0.134 | 0.131 | 0.128 | 0.125 | 0.123 | 0.120 | 0.118 | 0.115 | 0.111 | 0.109 |
| **17.5** | **0.104** | 0.131 | 0.128 | 0.126 | 0.123 | 0.120 | 0.118 | 0.116 | 0.113 | 0.111 | 0.109 | 0.106 | 0.102 | 0.100 |
| **18.0** | **0.096** | 0.120 | 0.118 | 0.116 | 0.113 | 0.111 | 0.109 | 0.106 | 0.104 | 0.102 | 0.100 | 0.098 | 0.094 | 0.093 |
| **18.5** | **0.089** | 0.111 | 0.108 | 0.106 | 0.104 | 0.102 | 0.100 | 0.098 | 0.096 | 0.094 | 0.092 | 0.091 | 0.087 | 0.086 |
| **19.0** | **0.081** | 0.099 | 0.098 | 0.096 | 0.094 | 0.092 | 0.091 | 0.089 | 0.087 | 0.085 | 0.084 | 0.082 | 0.080 | 0.078 |
| **19.5** | **0.073** | 0.089 | 0.087 | 0.086 | 0.084 | 0.083 | 0.081 | 0.080 | 0.078 | 0.077 | 0.076 | 0.074 | 0.072 | 0.071 |
| **20.0** | **0.065** | 0.078 | 0.077 | 0.076 | 0.075 | 0.073 | 0.072 | 0.071 | 0.070 | 0.069 | 0.068 | 0.066 | 0.064 | 0.063 |

## 7.6 Sound Curves, Sound Optimized Mode SO2

| Sound Power Level at Hub Height | |
|---|---|
| **Conditions for Sound Power Level:** | **Measurement standard IEC 61400-11 ed. 3**<br>**Maximum turbulence at hub height: 30%**<br>**Inflow angle (vertical): 0 ±2°**<br>**Air density: 1.225 kg/m$^3$** |
| **Wind speed at hub height [m/s]** | **Sound Power Level at Hub Height [dBA]**<br>**Sound Optimized Mode SO2 (Blades with serrated trailing edge)** |
| 3 | 91.3 |
| 4 | 91.5 |
| 5 | 93.9 |
| 6 | 96.9 |
| 7 | 99.7 |
| 8 | 102.0 |
| 9 | 102.0 |
| 10 | 102.0 |
| 11 | 102.0 |
| 12 | 102.0 |
| 13 | 102.0 |
| 14 | 102.0 |
| 15 | 102.0 |
| 16 | 102.0 |
| 17 | 102.0 |
| 18 | 102.0 |
| 19 | 102.0 |
| 20 | 102.0 |

## 7.7 Power Curves, Sound Optimized Mode SO3

| Air density [kg/m³] | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Wind speed [m/s]** | **1.225** | **0.950** | **0.975** | **1.000** | **1.025** | **1.050** | **1.075** | **1.100** | **1.125** | **1.150** | **1.175** | **1.200** | **1.250** | **1.275** |
| **3.0** | **42** | 13 | 16 | 18 | 20 | 23 | 25 | 28 | 31 | 33 | 36 | 39 | 45 | 48 |
| **3.5** | **138** | 87 | 92 | 97 | 101 | 106 | 111 | 115 | 120 | 124 | 129 | 134 | 143 | 147 |
| **4.0** | **252** | 177 | 184 | 191 | 197 | 204 | 211 | 218 | 225 | 232 | 239 | 246 | 259 | 266 |
| **4.5** | **393** | 286 | 295 | 305 | 315 | 325 | 334 | 344 | 354 | 364 | 373 | 383 | 403 | 412 |
| **5.0** | **567** | 421 | 434 | 448 | 461 | 474 | 487 | 501 | 514 | 527 | 540 | 553 | 580 | 593 |
| **5.5** | **780** | 586 | 603 | 621 | 639 | 656 | 674 | 692 | 709 | 727 | 745 | 763 | 798 | 816 |
| **6.0** | **1039** | 784 | 807 | 831 | 854 | 877 | 900 | 923 | 946 | 970 | 993 | 1016 | 1062 | 1085 |
| **6.5** | **1346** | 1021 | 1051 | 1080 | 1110 | 1140 | 1169 | 1199 | 1228 | 1258 | 1287 | 1316 | 1375 | 1404 |
| **7.0** | **1705** | 1300 | 1337 | 1374 | 1411 | 1448 | 1485 | 1522 | 1558 | 1595 | 1632 | 1668 | 1741 | 1778 |
| **7.5** | **2108** | 1614 | 1659 | 1704 | 1749 | 1794 | 1839 | 1884 | 1929 | 1974 | 2018 | 2063 | 2152 | 2196 |
| **8.0** | **2542** | 1953 | 2007 | 2060 | 2114 | 2168 | 2221 | 2275 | 2328 | 2382 | 2435 | 2489 | 2595 | 2648 |
| **8.5** | **2979** | 2292 | 2355 | 2418 | 2480 | 2543 | 2605 | 2667 | 2730 | 2792 | 2854 | 2917 | 3041 | 3103 |
| **9.0** | **3450** | 2660 | 2732 | 2804 | 2876 | 2948 | 3020 | 3092 | 3164 | 3236 | 3307 | 3378 | 3520 | 3590 |
| **9.5** | **3901** | 3019 | 3100 | 3181 | 3262 | 3344 | 3424 | 3505 | 3585 | 3666 | 3744 | 3822 | 3975 | 4048 |
| **10.0** | **4248** | 3327 | 3416 | 3505 | 3594 | 3683 | 3769 | 3855 | 3941 | 4026 | 4100 | 4174 | 4310 | 4372 |
| **10.5** | **4470** | 3587 | 3682 | 3776 | 3870 | 3965 | 4047 | 4129 | 4211 | 4293 | 4352 | 4411 | 4512 | 4554 |
| **11.0** | **4604** | 3816 | 3910 | 4003 | 4096 | 4190 | 4261 | 4332 | 4403 | 4474 | 4518 | 4561 | 4629 | 4653 |
| **11.5** | **4661** | 4003 | 4090 | 4177 | 4264 | 4351 | 4409 | 4466 | 4524 | 4581 | 4608 | 4635 | 4674 | 4686 |
| **12.0** | **4684** | 4131 | 4212 | 4292 | 4373 | 4454 | 4499 | 4543 | 4588 | 4633 | 4650 | 4667 | 4692 | 4700 |
| **12.5** | **4695** | 4218 | 4292 | 4366 | 4440 | 4514 | 4550 | 4586 | 4621 | 4657 | 4670 | 4682 | 4701 | 4707 |
| **13.0** | **4700** | 4289 | 4355 | 4422 | 4488 | 4555 | 4584 | 4613 | 4642 | 4671 | 4681 | 4690 | 4705 | 4710 |
| **13.5** | **4707** | 4338 | 4397 | 4456 | 4515 | 4574 | 4601 | 4627 | 4653 | 4679 | 4688 | 4698 | 4711 | 4715 |
| **14.0** | **4710** | 4388 | 4441 | 4494 | 4547 | 4600 | 4622 | 4644 | 4665 | 4687 | 4695 | 4702 | 4713 | 4716 |
| **14.5** | **4712** | 4430 | 4477 | 4525 | 4572 | 4620 | 4638 | 4657 | 4675 | 4694 | 4700 | 4706 | 4715 | 4718 |
| **15.0** | **4713** | 4457 | 4500 | 4544 | 4587 | 4630 | 4646 | 4662 | 4678 | 4695 | 4701 | 4707 | 4715 | 4717 |
| **15.5** | **4714** | 4469 | 4510 | 4551 | 4592 | 4633 | 4649 | 4665 | 4681 | 4696 | 4702 | 4708 | 4716 | 4718 |
| **16.0** | **4713** | 4473 | 4513 | 4552 | 4592 | 4632 | 4648 | 4664 | 4679 | 4695 | 4701 | 4707 | 4715 | 4717 |
| **16.5** | **4712** | 4474 | 4514 | 4553 | 4592 | 4631 | 4646 | 4662 | 4678 | 4693 | 4700 | 4706 | 4714 | 4717 |
| **17.0** | **4711** | 4476 | 4514 | 4553 | 4591 | 4629 | 4645 | 4660 | 4676 | 4692 | 4698 | 4705 | 4714 | 4716 |
| **17.5** | **4708** | 4454 | 4493 | 4532 | 4571 | 4610 | 4629 | 4647 | 4666 | 4685 | 4692 | 4700 | 4711 | 4715 |
| **18.0** | **4708** | 4464 | 4501 | 4539 | 4576 | 4614 | 4632 | 4650 | 4668 | 4686 | 4693 | 4701 | 4711 | 4714 |
| **18.5** | **4708** | 4478 | 4514 | 4550 | 4585 | 4621 | 4638 | 4655 | 4672 | 4688 | 4695 | 4702 | 4712 | 4715 |
| **19.0** | **4699** | 4477 | 4511 | 4544 | 4578 | 4612 | 4628 | 4644 | 4660 | 4676 | 4683 | 4691 | 4703 | 4706 |
| **19.5** | **4641** | 4421 | 4453 | 4485 | 4516 | 4548 | 4564 | 4581 | 4597 | 4614 | 4623 | 4632 | 4647 | 4653 |
| **20.0** | **4503** | 4282 | 4312 | 4343 | 4373 | 4403 | 4420 | 4437 | 4455 | 4472 | 4482 | 4493 | 4512 | 4520 |

## 7.8 Ct Values, Sound Optimized Mode SO3

| Air density kg/m³ | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Wind speed [m/s]** | **1.225** | **0.950** | **0.975** | **1.000** | **1.025** | **1.050** | **1.075** | **1.100** | **1.125** | **1.150** | **1.175** | **1.200** | **1.250** | **1.275** |
| **3.0** | **0.885** | 0.877 | 0.878 | 0.880 | 0.881 | 0.883 | 0.883 | 0.884 | 0.884 | 0.884 | 0.884 | 0.884 | 0.884 | 0.884 |
| **3.5** | **0.844** | 0.844 | 0.844 | 0.844 | 0.844 | 0.844 | 0.844 | 0.844 | 0.844 | 0.844 | 0.844 | 0.844 | 0.844 | 0.844 |
| **4.0** | **0.806** | 0.805 | 0.805 | 0.805 | 0.805 | 0.805 | 0.805 | 0.805 | 0.806 | 0.806 | 0.806 | 0.806 | 0.805 | 0.805 |
| **4.5** | **0.795** | 0.795 | 0.795 | 0.795 | 0.796 | 0.796 | 0.796 | 0.796 | 0.796 | 0.796 | 0.795 | 0.795 | 0.795 | 0.795 |
| **5.0** | **0.789** | 0.793 | 0.793 | 0.792 | 0.792 | 0.792 | 0.791 | 0.791 | 0.791 | 0.790 | 0.790 | 0.790 | 0.789 | 0.789 |
| **5.5** | **0.790** | 0.788 | 0.788 | 0.788 | 0.788 | 0.788 | 0.789 | 0.789 | 0.789 | 0.789 | 0.789 | 0.790 | 0.790 | 0.790 |
| **6.0** | **0.792** | 0.789 | 0.789 | 0.790 | 0.790 | 0.790 | 0.791 | 0.791 | 0.791 | 0.792 | 0.792 | 0.792 | 0.793 | 0.793 |
| **6.5** | **0.797** | 0.793 | 0.794 | 0.794 | 0.794 | 0.795 | 0.795 | 0.795 | 0.796 | 0.796 | 0.796 | 0.796 | 0.797 | 0.797 |
| **7.0** | **0.798** | 0.795 | 0.795 | 0.795 | 0.795 | 0.796 | 0.796 | 0.796 | 0.797 | 0.797 | 0.797 | 0.797 | 0.798 | 0.798 |
| **7.5** | **0.782** | 0.779 | 0.779 | 0.780 | 0.780 | 0.780 | 0.780 | 0.781 | 0.781 | 0.781 | 0.781 | 0.782 | 0.782 | 0.782 |
| **8.0** | **0.748** | 0.746 | 0.746 | 0.747 | 0.747 | 0.747 | 0.747 | 0.748 | 0.748 | 0.748 | 0.748 | 0.748 | 0.749 | 0.749 |
| **8.5** | **0.698** | 0.696 | 0.696 | 0.696 | 0.697 | 0.697 | 0.697 | 0.697 | 0.697 | 0.697 | 0.698 | 0.698 | 0.698 | 0.698 |
| **9.0** | **0.669** | 0.666 | 0.667 | 0.667 | 0.667 | 0.667 | 0.668 | 0.668 | 0.668 | 0.668 | 0.668 | 0.669 | 0.669 | 0.668 |
| **9.5** | **0.636** | 0.637 | 0.637 | 0.637 | 0.637 | 0.638 | 0.638 | 0.638 | 0.638 | 0.638 | 0.638 | 0.637 | 0.634 | 0.631 |
| **10.0** | **0.572** | 0.583 | 0.583 | 0.584 | 0.584 | 0.584 | 0.583 | 0.583 | 0.582 | 0.582 | 0.579 | 0.575 | 0.567 | 0.563 |
| **10.5** | **0.498** | 0.523 | 0.523 | 0.523 | 0.522 | 0.522 | 0.520 | 0.518 | 0.516 | 0.514 | 0.509 | 0.503 | 0.490 | 0.483 |
| **11.0** | **0.428** | 0.468 | 0.467 | 0.466 | 0.464 | 0.463 | 0.459 | 0.455 | 0.451 | 0.448 | 0.441 | 0.434 | 0.420 | 0.411 |
| **11.5** | **0.367** | 0.418 | 0.416 | 0.413 | 0.411 | 0.409 | 0.404 | 0.399 | 0.394 | 0.389 | 0.382 | 0.374 | 0.360 | 0.352 |
| **12.0** | **0.318** | 0.371 | 0.368 | 0.365 | 0.362 | 0.359 | 0.354 | 0.349 | 0.343 | 0.338 | 0.331 | 0.325 | 0.311 | 0.305 |
| **12.5** | **0.277** | 0.328 | 0.325 | 0.322 | 0.319 | 0.316 | 0.311 | 0.306 | 0.300 | 0.295 | 0.289 | 0.283 | 0.272 | 0.266 |
| **13.0** | **0.244** | 0.292 | 0.289 | 0.286 | 0.283 | 0.279 | 0.274 | 0.270 | 0.265 | 0.260 | 0.255 | 0.249 | 0.239 | 0.234 |
| **13.5** | **0.217** | 0.261 | 0.258 | 0.254 | 0.251 | 0.248 | 0.244 | 0.239 | 0.235 | 0.230 | 0.226 | 0.221 | 0.212 | 0.208 |
| **14.0** | **0.193** | 0.235 | 0.231 | 0.228 | 0.225 | 0.222 | 0.218 | 0.214 | 0.210 | 0.206 | 0.201 | 0.197 | 0.190 | 0.186 |
| **14.5** | **0.173** | 0.212 | 0.209 | 0.206 | 0.202 | 0.199 | 0.196 | 0.192 | 0.188 | 0.184 | 0.181 | 0.177 | 0.170 | 0.167 |
| **15.0** | **0.156** | 0.191 | 0.189 | 0.186 | 0.183 | 0.180 | 0.176 | 0.173 | 0.169 | 0.166 | 0.163 | 0.160 | 0.153 | 0.150 |
| **15.5** | **0.142** | 0.173 | 0.171 | 0.168 | 0.165 | 0.162 | 0.159 | 0.156 | 0.153 | 0.150 | 0.147 | 0.144 | 0.139 | 0.136 |
| **16.0** | **0.129** | 0.157 | 0.155 | 0.152 | 0.150 | 0.147 | 0.145 | 0.142 | 0.139 | 0.136 | 0.134 | 0.131 | 0.126 | 0.124 |
| **16.5** | **0.117** | 0.143 | 0.141 | 0.139 | 0.136 | 0.134 | 0.132 | 0.129 | 0.127 | 0.124 | 0.122 | 0.120 | 0.115 | 0.113 |
| **17.0** | **0.108** | 0.131 | 0.129 | 0.127 | 0.125 | 0.123 | 0.120 | 0.118 | 0.116 | 0.114 | 0.112 | 0.110 | 0.106 | 0.104 |
| **17.5** | **0.099** | 0.120 | 0.118 | 0.116 | 0.114 | 0.113 | 0.111 | 0.109 | 0.107 | 0.105 | 0.103 | 0.101 | 0.097 | 0.096 |
| **18.0** | **0.091** | 0.111 | 0.109 | 0.107 | 0.105 | 0.104 | 0.102 | 0.100 | 0.098 | 0.097 | 0.095 | 0.093 | 0.090 | 0.088 |
| **18.5** | **0.085** | 0.102 | 0.101 | 0.099 | 0.097 | 0.096 | 0.094 | 0.093 | 0.091 | 0.089 | 0.088 | 0.086 | 0.083 | 0.082 |
| **19.0** | **0.078** | 0.094 | 0.093 | 0.091 | 0.090 | 0.088 | 0.087 | 0.085 | 0.084 | 0.082 | 0.081 | 0.079 | 0.077 | 0.075 |
| **19.5** | **0.072** | 0.086 | 0.085 | 0.084 | 0.082 | 0.081 | 0.079 | 0.078 | 0.077 | 0.075 | 0.074 | 0.073 | 0.070 | 0.069 |
| **20.0** | **0.065** | 0.078 | 0.077 | 0.076 | 0.074 | 0.073 | 0.072 | 0.071 | 0.069 | 0.068 | 0.067 | 0.066 | 0.064 | 0.063 |

## 7.9 Sound Curves, Sound Optimized Mode SO3

| Sound Power Level at Hub Height | |
|---|---|
| **Conditions for Sound Power Level:** | **Measurement standard IEC 61400-11 ed. 3**<br>**Maximum turbulence at hub height: 30%**<br>**Inflow angle (vertical): 0 ±2°**<br>**Air density: 1.225 kg/m$^3$** |
| **Wind speed at hub height [m/s]** | **Sound Power Level at Hub Height [dBA]**<br>**Sound Optimized Mode SO3 (Blades with serrated trailing edge)** |
| 3 | 91.3 |
| 4 | 91.5 |
| 5 | 93.9 |
| 6 | 96.9 |
| 7 | 99.7 |
| 8 | 101.0 |
| 9 | 101.0 |
| 10 | 101.0 |
| 11 | 101.0 |
| 12 | 101.0 |
| 13 | 101.0 |
| 14 | 101.0 |
| 15 | 101.0 |
| 16 | 101.0 |
| 17 | 101.0 |
| 18 | 101.0 |
| 19 | 101.0 |
| 20 | 101.0 |

## 7.10 Power Curves, Sound Optimized Mode SO4

| Air density [kg/m³] | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Wind speed [m/s]** | **1.225** | **0.950** | **0.975** | **1.000** | **1.025** | **1.050** | **1.075** | **1.100** | **1.125** | **1.150** | **1.175** | **1.200** | **1.250** | **1.275** |
| **3.0** | **42** | 13 | 16 | 18 | 20 | 23 | 25 | 28 | 31 | 33 | 36 | 39 | 45 | 48 |
| **3.5** | **138** | 87 | 92 | 97 | 101 | 106 | 111 | 115 | 120 | 124 | 129 | 134 | 143 | 147 |
| **4.0** | **252** | 177 | 184 | 191 | 197 | 204 | 211 | 218 | 225 | 232 | 239 | 246 | 259 | 266 |
| **4.5** | **393** | 286 | 295 | 305 | 315 | 325 | 334 | 344 | 354 | 364 | 373 | 383 | 403 | 412 |
| **5.0** | **567** | 421 | 434 | 448 | 461 | 474 | 487 | 501 | 514 | 527 | 540 | 553 | 580 | 593 |
| **5.5** | **780** | 586 | 603 | 621 | 639 | 656 | 674 | 692 | 709 | 727 | 745 | 763 | 798 | 816 |
| **6.0** | **1039** | 785 | 808 | 831 | 854 | 877 | 900 | 923 | 947 | 970 | 993 | 1016 | 1062 | 1086 |
| **6.5** | **1346** | 1021 | 1051 | 1080 | 1110 | 1140 | 1169 | 1199 | 1228 | 1258 | 1287 | 1317 | 1375 | 1404 |
| **7.0** | **1702** | 1299 | 1336 | 1373 | 1409 | 1446 | 1483 | 1520 | 1556 | 1593 | 1630 | 1666 | 1739 | 1776 |
| **7.5** | **2092** | 1603 | 1647 | 1692 | 1736 | 1781 | 1825 | 1870 | 1914 | 1959 | 2003 | 2048 | 2136 | 2180 |
| **8.0** | **2498** | 1919 | 1972 | 2025 | 2077 | 2130 | 2183 | 2236 | 2288 | 2341 | 2394 | 2446 | 2551 | 2604 |
| **8.5** | **2898** | 2229 | 2290 | 2351 | 2412 | 2473 | 2534 | 2594 | 2655 | 2716 | 2777 | 2837 | 2958 | 3018 |
| **9.0** | **3303** | 2547 | 2616 | 2685 | 2754 | 2823 | 2892 | 2960 | 3029 | 3098 | 3166 | 3235 | 3372 | 3440 |
| **9.5** | **3664** | 2830 | 2907 | 2983 | 3059 | 3136 | 3212 | 3288 | 3364 | 3440 | 3515 | 3589 | 3736 | 3808 |
| **10.0** | **3945** | 3066 | 3148 | 3230 | 3313 | 3395 | 3476 | 3558 | 3639 | 3720 | 3795 | 3870 | 4010 | 4075 |
| **10.5** | **4147** | 3266 | 3354 | 3441 | 3528 | 3616 | 3698 | 3780 | 3863 | 3945 | 4012 | 4080 | 4197 | 4247 |
| **11.0** | **4271** | 3434 | 3525 | 3616 | 3707 | 3798 | 3873 | 3948 | 4024 | 4099 | 4157 | 4214 | 4310 | 4349 |
| **11.5** | **4338** | 3555 | 3646 | 3736 | 3826 | 3917 | 3987 | 4057 | 4128 | 4198 | 4245 | 4292 | 4367 | 4396 |
| **12.0** | **4375** | 3650 | 3737 | 3824 | 3911 | 3998 | 4063 | 4127 | 4192 | 4256 | 4296 | 4336 | 4396 | 4417 |
| **12.5** | **4396** | 3731 | 3814 | 3898 | 3982 | 4065 | 4124 | 4182 | 4240 | 4299 | 4331 | 4364 | 4413 | 4430 |
| **13.0** | **4412** | 3804 | 3883 | 3962 | 4042 | 4121 | 4174 | 4227 | 4280 | 4333 | 4359 | 4386 | 4425 | 4438 |
| **13.5** | **4420** | 3869 | 3942 | 4016 | 4089 | 4162 | 4209 | 4256 | 4302 | 4349 | 4373 | 4396 | 4432 | 4445 |
| **14.0** | **4429** | 3922 | 3992 | 4061 | 4131 | 4200 | 4242 | 4284 | 4327 | 4369 | 4389 | 4409 | 4440 | 4451 |
| **14.5** | **4434** | 3955 | 4022 | 4088 | 4155 | 4221 | 4260 | 4300 | 4339 | 4378 | 4396 | 4415 | 4444 | 4454 |
| **15.0** | **4430** | 3963 | 4028 | 4094 | 4159 | 4225 | 4262 | 4300 | 4338 | 4376 | 4394 | 4412 | 4440 | 4450 |
| **15.5** | **4429** | 3970 | 4034 | 4099 | 4163 | 4227 | 4264 | 4301 | 4338 | 4375 | 4393 | 4411 | 4439 | 4448 |
| **16.0** | **4427** | 3977 | 4040 | 4103 | 4166 | 4229 | 4265 | 4301 | 4338 | 4374 | 4392 | 4409 | 4437 | 4447 |
| **16.5** | **4426** | 3988 | 4050 | 4111 | 4172 | 4234 | 4269 | 4304 | 4339 | 4374 | 4392 | 4409 | 4436 | 4446 |
| **17.0** | **4426** | 4004 | 4064 | 4124 | 4184 | 4243 | 4276 | 4310 | 4343 | 4376 | 4393 | 4410 | 4436 | 4446 |
| **17.5** | **4419** | 4010 | 4065 | 4120 | 4175 | 4230 | 4263 | 4296 | 4329 | 4362 | 4381 | 4400 | 4430 | 4442 |
| **18.0** | **4424** | 4038 | 4091 | 4143 | 4195 | 4247 | 4278 | 4309 | 4340 | 4370 | 4388 | 4406 | 4434 | 4445 |
| **18.5** | **4429** | 4071 | 4120 | 4169 | 4218 | 4267 | 4295 | 4324 | 4352 | 4381 | 4397 | 4413 | 4439 | 4448 |
| **19.0** | **4427** | 4093 | 4140 | 4188 | 4235 | 4282 | 4308 | 4334 | 4359 | 4385 | 4399 | 4413 | 4436 | 4445 |
| **19.5** | **4430** | 4129 | 4171 | 4214 | 4256 | 4299 | 4322 | 4345 | 4368 | 4391 | 4404 | 4417 | 4437 | 4445 |
| **20.0** | **4384** | 4123 | 4159 | 4196 | 4232 | 4268 | 4288 | 4309 | 4329 | 4349 | 4360 | 4372 | 4392 | 4400 |

## 7.11 Ct Values, Sound Optimized Mode SO4

| Air density kg/m³ | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Wind speed [m/s]** | **1.225** | **0.950** | **0.975** | **1.000** | **1.025** | **1.050** | **1.075** | **1.100** | **1.125** | **1.150** | **1.175** | **1.200** | **1.250** | **1.275** |
| **3.0** | **0.885** | 0.877 | 0.878 | 0.880 | 0.881 | 0.883 | 0.883 | 0.884 | 0.884 | 0.884 | 0.884 | 0.884 | 0.884 | 0.884 |
| **3.5** | **0.844** | 0.844 | 0.844 | 0.844 | 0.844 | 0.844 | 0.844 | 0.844 | 0.844 | 0.844 | 0.844 | 0.844 | 0.844 | 0.844 |
| **4.0** | **0.806** | 0.805 | 0.805 | 0.805 | 0.805 | 0.805 | 0.805 | 0.805 | 0.806 | 0.806 | 0.806 | 0.806 | 0.805 | 0.805 |
| **4.5** | **0.795** | 0.795 | 0.795 | 0.795 | 0.796 | 0.796 | 0.796 | 0.796 | 0.796 | 0.796 | 0.795 | 0.795 | 0.795 | 0.795 |
| **5.0** | **0.789** | 0.793 | 0.793 | 0.792 | 0.792 | 0.792 | 0.791 | 0.791 | 0.791 | 0.790 | 0.790 | 0.790 | 0.789 | 0.789 |
| **5.5** | **0.790** | 0.789 | 0.788 | 0.788 | 0.788 | 0.788 | 0.789 | 0.789 | 0.789 | 0.789 | 0.790 | 0.790 | 0.790 | 0.790 |
| **6.0** | **0.794** | 0.790 | 0.791 | 0.791 | 0.791 | 0.792 | 0.792 | 0.792 | 0.792 | 0.793 | 0.793 | 0.793 | 0.794 | 0.794 |
| **6.5** | **0.796** | 0.792 | 0.793 | 0.793 | 0.793 | 0.794 | 0.794 | 0.794 | 0.795 | 0.795 | 0.795 | 0.795 | 0.796 | 0.796 |
| **7.0** | **0.791** | 0.788 | 0.788 | 0.789 | 0.789 | 0.789 | 0.789 | 0.790 | 0.790 | 0.790 | 0.790 | 0.791 | 0.791 | 0.791 |
| **7.5** | **0.761** | 0.759 | 0.759 | 0.759 | 0.759 | 0.760 | 0.760 | 0.760 | 0.760 | 0.760 | 0.761 | 0.761 | 0.761 | 0.761 |
| **8.0** | **0.717** | 0.715 | 0.715 | 0.716 | 0.716 | 0.716 | 0.716 | 0.716 | 0.717 | 0.717 | 0.717 | 0.717 | 0.718 | 0.718 |
| **8.5** | **0.665** | 0.663 | 0.663 | 0.663 | 0.663 | 0.663 | 0.664 | 0.664 | 0.664 | 0.664 | 0.664 | 0.665 | 0.665 | 0.665 |
| **9.0** | **0.626** | 0.624 | 0.624 | 0.624 | 0.624 | 0.625 | 0.625 | 0.625 | 0.625 | 0.625 | 0.625 | 0.626 | 0.626 | 0.626 |
| **9.5** | **0.576** | 0.575 | 0.575 | 0.575 | 0.575 | 0.575 | 0.576 | 0.576 | 0.576 | 0.576 | 0.576 | 0.576 | 0.575 | 0.574 |
| **10.0** | **0.512** | 0.516 | 0.516 | 0.516 | 0.516 | 0.516 | 0.516 | 0.516 | 0.516 | 0.516 | 0.515 | 0.513 | 0.510 | 0.507 |
| **10.5** | **0.449** | 0.459 | 0.459 | 0.459 | 0.460 | 0.460 | 0.459 | 0.458 | 0.457 | 0.457 | 0.454 | 0.452 | 0.444 | 0.440 |
| **11.0** | **0.390** | 0.409 | 0.409 | 0.409 | 0.409 | 0.409 | 0.407 | 0.405 | 0.403 | 0.401 | 0.397 | 0.394 | 0.385 | 0.380 |
| **11.5** | **0.338** | 0.362 | 0.362 | 0.361 | 0.361 | 0.360 | 0.358 | 0.356 | 0.353 | 0.351 | 0.347 | 0.343 | 0.333 | 0.328 |
| **12.0** | **0.295** | 0.321 | 0.320 | 0.319 | 0.318 | 0.317 | 0.315 | 0.312 | 0.310 | 0.307 | 0.303 | 0.299 | 0.290 | 0.285 |
| **12.5** | **0.259** | 0.286 | 0.285 | 0.284 | 0.283 | 0.281 | 0.279 | 0.276 | 0.273 | 0.271 | 0.267 | 0.263 | 0.254 | 0.250 |
| **13.0** | **0.229** | 0.256 | 0.255 | 0.254 | 0.252 | 0.251 | 0.248 | 0.245 | 0.243 | 0.240 | 0.236 | 0.232 | 0.225 | 0.220 |
| **13.5** | **0.203** | 0.231 | 0.229 | 0.228 | 0.226 | 0.224 | 0.222 | 0.219 | 0.216 | 0.214 | 0.210 | 0.207 | 0.200 | 0.196 |
| **14.0** | **0.182** | 0.209 | 0.207 | 0.205 | 0.204 | 0.202 | 0.199 | 0.197 | 0.194 | 0.191 | 0.188 | 0.185 | 0.179 | 0.175 |
| **14.5** | **0.163** | 0.188 | 0.187 | 0.185 | 0.183 | 0.182 | 0.179 | 0.177 | 0.174 | 0.172 | 0.169 | 0.166 | 0.160 | 0.158 |
| **15.0** | **0.147** | 0.170 | 0.168 | 0.167 | 0.165 | 0.164 | 0.161 | 0.159 | 0.157 | 0.155 | 0.152 | 0.150 | 0.145 | 0.142 |
| **15.5** | **0.133** | 0.154 | 0.152 | 0.151 | 0.150 | 0.148 | 0.146 | 0.144 | 0.142 | 0.140 | 0.138 | 0.135 | 0.131 | 0.129 |
| **16.0** | **0.121** | 0.140 | 0.138 | 0.137 | 0.136 | 0.134 | 0.133 | 0.131 | 0.129 | 0.127 | 0.125 | 0.123 | 0.119 | 0.117 |
| **16.5** | **0.110** | 0.128 | 0.126 | 0.125 | 0.124 | 0.123 | 0.121 | 0.119 | 0.118 | 0.116 | 0.114 | 0.112 | 0.109 | 0.107 |
| **17.0** | **0.101** | 0.117 | 0.116 | 0.115 | 0.114 | 0.113 | 0.111 | 0.109 | 0.108 | 0.106 | 0.105 | 0.103 | 0.099 | 0.098 |
| **17.5** | **0.093** | 0.108 | 0.107 | 0.106 | 0.105 | 0.103 | 0.102 | 0.101 | 0.099 | 0.098 | 0.096 | 0.095 | 0.092 | 0.090 |
| **18.0** | **0.086** | 0.100 | 0.099 | 0.098 | 0.097 | 0.096 | 0.094 | 0.093 | 0.092 | 0.090 | 0.089 | 0.087 | 0.085 | 0.083 |
| **18.5** | **0.080** | 0.093 | 0.092 | 0.091 | 0.090 | 0.089 | 0.087 | 0.086 | 0.085 | 0.084 | 0.082 | 0.081 | 0.078 | 0.077 |
| **19.0** | **0.074** | 0.086 | 0.085 | 0.084 | 0.083 | 0.082 | 0.081 | 0.080 | 0.078 | 0.077 | 0.076 | 0.075 | 0.072 | 0.071 |
| **19.5** | **0.068** | 0.081 | 0.080 | 0.079 | 0.078 | 0.077 | 0.075 | 0.074 | 0.073 | 0.072 | 0.071 | 0.070 | 0.067 | 0.066 |
| **20.0** | **0.063** | 0.075 | 0.074 | 0.073 | 0.072 | 0.071 | 0.070 | 0.069 | 0.067 | 0.066 | 0.065 | 0.064 | 0.062 | 0.061 |

## 7.12 Sound Curves, Sound Optimized Mode SO4

| Sound Power Level at Hub Height | |
|---|---|
| **Conditions for Sound Power Level:** | **Measurement standard IEC 61400-11 ed. 3**<br>**Maximum turbulence at hub height: 30%**<br>**Inflow angle (vertical): 0 ±2°**<br>**Air density: 1.225 kg/m$^3$** |
| **Wind speed at hub height [m/s]** | **Sound Power Level at Hub Height [dBA]**<br>**Sound Optimized Mode SO4 (Blades with serrated trailing edge)** |
| 3 | 91.3 |
| 4 | 91.5 |
| 5 | 93.9 |
| 6 | 96.9 |
| 7 | 99.5 |
| 8 | 100.0 |
| 9 | 100.0 |
| 10 | 100.0 |
| 11 | 100.0 |
| 12 | 100.0 |
| 13 | 100.0 |
| 14 | 100.0 |
| 15 | 100.0 |
| 16 | 100.0 |
| 17 | 100.0 |
| 18 | 100.0 |
| 19 | 100.0 |
| 20 | 100.0 |

## 7.13 Power Curves, Sound Optimized Mode SO5

| Air density [kg/m³] | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Wind speed [m/s]** | **1.225** | **0.950** | **0.975** | **1.000** | **1.025** | **1.050** | **1.075** | **1.100** | **1.125** | **1.150** | **1.175** | **1.200** | **1.250** | **1.275** |
| **3.0** | **42** | 13 | 16 | 18 | 20 | 23 | 25 | 28 | 31 | 33 | 36 | 39 | 45 | 48 |
| **3.5** | **138** | 87 | 92 | 97 | 101 | 106 | 111 | 115 | 120 | 124 | 129 | 134 | 143 | 147 |
| **4.0** | **252** | 177 | 184 | 191 | 197 | 204 | 211 | 218 | 225 | 232 | 239 | 246 | 259 | 266 |
| **4.5** | **393** | 286 | 295 | 305 | 315 | 325 | 334 | 344 | 354 | 364 | 373 | 383 | 403 | 412 |
| **5.0** | **567** | 421 | 434 | 448 | 461 | 474 | 487 | 501 | 514 | 527 | 540 | 553 | 580 | 593 |
| **5.5** | **781** | 586 | 604 | 621 | 639 | 656 | 674 | 692 | 710 | 727 | 745 | 763 | 798 | 816 |
| **6.0** | **1040** | 785 | 808 | 831 | 854 | 878 | 901 | 924 | 947 | 970 | 993 | 1017 | 1063 | 1086 |
| **6.5** | **1343** | 1019 | 1049 | 1078 | 1108 | 1137 | 1167 | 1196 | 1225 | 1255 | 1284 | 1313 | 1372 | 1401 |
| **7.0** | **1689** | 1289 | 1325 | 1362 | 1398 | 1435 | 1471 | 1508 | 1544 | 1580 | 1617 | 1653 | 1726 | 1762 |
| **7.5** | **2056** | 1575 | 1619 | 1662 | 1706 | 1750 | 1794 | 1838 | 1881 | 1925 | 1969 | 2012 | 2100 | 2143 |
| **8.0** | **2428** | 1865 | 1916 | 1968 | 2019 | 2070 | 2121 | 2173 | 2224 | 2275 | 2326 | 2377 | 2480 | 2531 |
| **8.5** | **2780** | 2139 | 2197 | 2256 | 2314 | 2373 | 2431 | 2489 | 2548 | 2606 | 2664 | 2722 | 2838 | 2896 |
| **9.0** | **3101** | 2390 | 2454 | 2519 | 2584 | 2649 | 2714 | 2778 | 2843 | 2908 | 2972 | 3037 | 3166 | 3230 |
| **9.5** | **3365** | 2594 | 2665 | 2735 | 2805 | 2875 | 2945 | 3016 | 3086 | 3156 | 3225 | 3295 | 3434 | 3504 |
| **10.0** | **3588** | 2770 | 2845 | 2920 | 2995 | 3070 | 3144 | 3219 | 3293 | 3368 | 3441 | 3515 | 3659 | 3730 |
| **10.5** | **3758** | 2910 | 2988 | 3067 | 3145 | 3224 | 3301 | 3379 | 3456 | 3534 | 3609 | 3683 | 3828 | 3898 |
| **11.0** | **3873** | 3017 | 3098 | 3179 | 3260 | 3341 | 3421 | 3501 | 3581 | 3661 | 3732 | 3802 | 3936 | 3998 |
| **11.5** | **3952** | 3098 | 3181 | 3264 | 3347 | 3430 | 3510 | 3590 | 3669 | 3749 | 3817 | 3884 | 4009 | 4065 |
| **12.0** | **4012** | 3172 | 3256 | 3341 | 3426 | 3510 | 3588 | 3665 | 3743 | 3820 | 3884 | 3948 | 4064 | 4115 |
| **12.5** | **4066** | 3246 | 3332 | 3418 | 3504 | 3590 | 3665 | 3739 | 3814 | 3889 | 3948 | 4007 | 4113 | 4160 |
| **13.0** | **4112** | 3317 | 3403 | 3489 | 3575 | 3661 | 3733 | 3804 | 3876 | 3948 | 4002 | 4057 | 4155 | 4197 |
| **13.5** | **4131** | 3369 | 3454 | 3539 | 3623 | 3708 | 3775 | 3842 | 3910 | 3977 | 4028 | 4080 | 4169 | 4208 |
| **14.0** | **4140** | 3398 | 3481 | 3565 | 3648 | 3731 | 3796 | 3861 | 3926 | 3992 | 4041 | 4090 | 4176 | 4213 |
| **14.5** | **4140** | 3413 | 3495 | 3577 | 3659 | 3741 | 3805 | 3868 | 3931 | 3995 | 4043 | 4092 | 4176 | 4212 |
| **15.0** | **4143** | 3427 | 3507 | 3587 | 3667 | 3746 | 3810 | 3873 | 3936 | 4000 | 4047 | 4095 | 4177 | 4211 |
| **15.5** | **4145** | 3445 | 3524 | 3602 | 3680 | 3758 | 3821 | 3883 | 3945 | 4007 | 4053 | 4099 | 4178 | 4212 |
| **16.0** | **4153** | 3470 | 3547 | 3624 | 3700 | 3777 | 3838 | 3898 | 3959 | 4019 | 4064 | 4108 | 4184 | 4216 |
| **16.5** | **4166** | 3504 | 3579 | 3654 | 3729 | 3804 | 3863 | 3922 | 3980 | 4039 | 4081 | 4124 | 4196 | 4226 |
| **17.0** | **4184** | 3548 | 3621 | 3694 | 3768 | 3841 | 3897 | 3954 | 4010 | 4066 | 4106 | 4145 | 4211 | 4239 |
| **17.5** | **4173** | 3586 | 3655 | 3724 | 3793 | 3862 | 3913 | 3964 | 4015 | 4066 | 4102 | 4138 | 4200 | 4227 |
| **18.0** | **4195** | 3638 | 3705 | 3772 | 3838 | 3905 | 3953 | 4001 | 4049 | 4097 | 4130 | 4163 | 4219 | 4244 |
| **18.5** | **4219** | 3697 | 3761 | 3825 | 3889 | 3953 | 3997 | 4042 | 4086 | 4130 | 4160 | 4189 | 4240 | 4262 |
| **19.0** | **4236** | 3760 | 3818 | 3876 | 3934 | 3992 | 4034 | 4075 | 4117 | 4158 | 4184 | 4210 | 4254 | 4271 |
| **19.5** | **4260** | 3830 | 3884 | 3939 | 3993 | 4047 | 4084 | 4121 | 4157 | 4194 | 4216 | 4238 | 4276 | 4291 |
| **20.0** | **4260** | 3884 | 3933 | 3982 | 4031 | 4080 | 4111 | 4142 | 4173 | 4204 | 4223 | 4241 | 4273 | 4286 |

## 7.14 Ct Values, Sound Optimized Mode SO5

| Air density kg/m³ | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Wind speed [m/s]** | **1.225** | **0.950** | **0.975** | **1.000** | **1.025** | **1.050** | **1.075** | **1.100** | **1.125** | **1.150** | **1.175** | **1.200** | **1.250** | **1.275** |
| **3.0** | **0.885** | 0.877 | 0.878 | 0.880 | 0.881 | 0.883 | 0.883 | 0.884 | 0.884 | 0.884 | 0.884 | 0.884 | 0.884 | 0.884 |
| **3.5** | **0.844** | 0.844 | 0.844 | 0.844 | 0.844 | 0.844 | 0.844 | 0.844 | 0.844 | 0.844 | 0.844 | 0.844 | 0.844 | 0.844 |
| **4.0** | **0.806** | 0.805 | 0.805 | 0.805 | 0.805 | 0.805 | 0.805 | 0.805 | 0.806 | 0.806 | 0.806 | 0.806 | 0.805 | 0.805 |
| **4.5** | **0.795** | 0.794 | 0.795 | 0.795 | 0.796 | 0.796 | 0.796 | 0.796 | 0.796 | 0.796 | 0.795 | 0.795 | 0.795 | 0.795 |
| **5.0** | **0.789** | 0.793 | 0.793 | 0.792 | 0.792 | 0.792 | 0.791 | 0.791 | 0.791 | 0.790 | 0.790 | 0.790 | 0.789 | 0.789 |
| **5.5** | **0.791** | 0.789 | 0.789 | 0.789 | 0.789 | 0.789 | 0.790 | 0.790 | 0.790 | 0.790 | 0.791 | 0.791 | 0.791 | 0.792 |
| **6.0** | **0.795** | 0.792 | 0.792 | 0.792 | 0.793 | 0.793 | 0.793 | 0.794 | 0.794 | 0.794 | 0.794 | 0.795 | 0.795 | 0.795 |
| **6.5** | **0.785** | 0.782 | 0.783 | 0.783 | 0.783 | 0.784 | 0.784 | 0.784 | 0.784 | 0.785 | 0.785 | 0.785 | 0.785 | 0.786 |
| **7.0** | **0.764** | 0.762 | 0.762 | 0.762 | 0.762 | 0.762 | 0.763 | 0.763 | 0.763 | 0.763 | 0.764 | 0.764 | 0.764 | 0.764 |
| **7.5** | **0.726** | 0.724 | 0.724 | 0.724 | 0.724 | 0.725 | 0.725 | 0.725 | 0.725 | 0.725 | 0.726 | 0.726 | 0.726 | 0.726 |
| **8.0** | **0.681** | 0.679 | 0.679 | 0.679 | 0.679 | 0.680 | 0.680 | 0.680 | 0.680 | 0.680 | 0.681 | 0.681 | 0.681 | 0.681 |
| **8.5** | **0.627** | 0.626 | 0.626 | 0.626 | 0.626 | 0.626 | 0.626 | 0.627 | 0.627 | 0.627 | 0.627 | 0.627 | 0.628 | 0.628 |
| **9.0** | **0.572** | 0.570 | 0.571 | 0.571 | 0.571 | 0.571 | 0.571 | 0.571 | 0.571 | 0.572 | 0.572 | 0.572 | 0.572 | 0.572 |
| **9.5** | **0.509** | 0.508 | 0.508 | 0.508 | 0.509 | 0.509 | 0.509 | 0.509 | 0.509 | 0.509 | 0.509 | 0.509 | 0.510 | 0.510 |
| **10.0** | **0.451** | 0.451 | 0.451 | 0.451 | 0.451 | 0.451 | 0.451 | 0.451 | 0.451 | 0.451 | 0.451 | 0.451 | 0.451 | 0.450 |
| **10.5** | **0.397** | 0.398 | 0.398 | 0.398 | 0.398 | 0.398 | 0.398 | 0.398 | 0.398 | 0.398 | 0.398 | 0.397 | 0.396 | 0.395 |
| **11.0** | **0.348** | 0.351 | 0.351 | 0.351 | 0.351 | 0.351 | 0.351 | 0.351 | 0.351 | 0.351 | 0.350 | 0.349 | 0.346 | 0.344 |
| **11.5** | **0.305** | 0.309 | 0.309 | 0.309 | 0.309 | 0.309 | 0.309 | 0.309 | 0.309 | 0.308 | 0.307 | 0.306 | 0.303 | 0.300 |
| **12.0** | **0.268** | 0.275 | 0.275 | 0.275 | 0.275 | 0.275 | 0.274 | 0.274 | 0.273 | 0.273 | 0.271 | 0.270 | 0.266 | 0.264 |
| **12.5** | **0.238** | 0.246 | 0.246 | 0.246 | 0.246 | 0.246 | 0.245 | 0.244 | 0.244 | 0.243 | 0.241 | 0.240 | 0.236 | 0.234 |
| **13.0** | **0.212** | 0.222 | 0.222 | 0.222 | 0.221 | 0.221 | 0.220 | 0.219 | 0.219 | 0.218 | 0.216 | 0.214 | 0.210 | 0.208 |
| **13.5** | **0.190** | 0.200 | 0.200 | 0.200 | 0.199 | 0.199 | 0.198 | 0.197 | 0.196 | 0.195 | 0.193 | 0.191 | 0.188 | 0.186 |
| **14.0** | **0.170** | 0.180 | 0.180 | 0.179 | 0.179 | 0.179 | 0.178 | 0.177 | 0.176 | 0.174 | 0.173 | 0.171 | 0.168 | 0.166 |
| **14.5** | **0.152** | 0.162 | 0.162 | 0.161 | 0.161 | 0.161 | 0.160 | 0.159 | 0.158 | 0.157 | 0.155 | 0.154 | 0.151 | 0.149 |
| **15.0** | **0.138** | 0.147 | 0.146 | 0.146 | 0.145 | 0.145 | 0.144 | 0.143 | 0.142 | 0.141 | 0.140 | 0.139 | 0.136 | 0.134 |
| **15.5** | **0.125** | 0.133 | 0.133 | 0.133 | 0.132 | 0.132 | 0.131 | 0.130 | 0.129 | 0.128 | 0.127 | 0.126 | 0.123 | 0.122 |
| **16.0** | **0.114** | 0.122 | 0.122 | 0.121 | 0.121 | 0.120 | 0.119 | 0.119 | 0.118 | 0.117 | 0.116 | 0.115 | 0.112 | 0.111 |
| **16.5** | **0.104** | 0.112 | 0.112 | 0.111 | 0.111 | 0.110 | 0.110 | 0.109 | 0.108 | 0.107 | 0.106 | 0.105 | 0.103 | 0.102 |
| **17.0** | **0.096** | 0.104 | 0.104 | 0.103 | 0.103 | 0.102 | 0.101 | 0.101 | 0.100 | 0.099 | 0.098 | 0.097 | 0.095 | 0.093 |
| **17.5** | **0.088** | 0.097 | 0.096 | 0.096 | 0.095 | 0.095 | 0.094 | 0.093 | 0.092 | 0.091 | 0.090 | 0.089 | 0.087 | 0.086 |
| **18.0** | **0.082** | 0.091 | 0.090 | 0.089 | 0.089 | 0.088 | 0.087 | 0.086 | 0.086 | 0.085 | 0.084 | 0.083 | 0.081 | 0.080 |
| **18.5** | **0.076** | 0.085 | 0.084 | 0.084 | 0.083 | 0.082 | 0.082 | 0.081 | 0.080 | 0.079 | 0.078 | 0.077 | 0.075 | 0.074 |
| **19.0** | **0.070** | 0.080 | 0.079 | 0.078 | 0.077 | 0.077 | 0.076 | 0.075 | 0.074 | 0.073 | 0.072 | 0.071 | 0.069 | 0.069 |
| **19.5** | **0.066** | 0.075 | 0.074 | 0.074 | 0.073 | 0.072 | 0.071 | 0.070 | 0.070 | 0.069 | 0.068 | 0.067 | 0.065 | 0.064 |
| **20.0** | **0.061** | 0.071 | 0.070 | 0.069 | 0.069 | 0.068 | 0.067 | 0.066 | 0.065 | 0.064 | 0.063 | 0.062 | 0.061 | 0.060 |

## 7.15 Sound Curves, Sound Optimized Mode SO5

| Sound Power Level at Hub Height | |
|---|---|
| **Conditions for Sound Power Level:** | **Measurement standard IEC 61400-11 ed. 3**<br>**Maximum turbulence at hub height: 30%**<br>**Inflow angle (vertical): 0 ±2°**<br>**Air density: 1.225 kg/m$^3$** |
| **Wind speed at hub height [m/s]** | **Sound Power Level at Hub Height [dBA]**<br>**Sound Optimized Mode SO5 (Blades with serrated trailing edge)** |
| 3 | 91.3 |
| 4 | 91.5 |
| 5 | 93.9 |
| 6 | 96.9 |
| 7 | 98.7 |
| 8 | 99.0 |
| 9 | 99.0 |
| 10 | 99.0 |
| 11 | 99.0 |
| 12 | 99.0 |
| 13 | 99.0 |
| 14 | 99.0 |
| 15 | 99.0 |
| 16 | 99.0 |
| 17 | 99.0 |
| 18 | 99.0 |
| 19 | 99.0 |
| 20 | 99.0 |

## 7.16 Power Curves, Sound Optimized Mode SO6

| Air density [kg/m³] | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Wind speed [m/s]** | **1.225** | **0.950** | **0.975** | **1.000** | **1.025** | **1.050** | **1.075** | **1.100** | **1.125** | **1.150** | **1.175** | **1.200** | **1.250** | **1.275** |
| **3.0** | **42** | 13 | 16 | 18 | 20 | 23 | 25 | 28 | 31 | 33 | 36 | 39 | 45 | 48 |
| **3.5** | **138** | 87 | 92 | 97 | 101 | 106 | 111 | 115 | 120 | 124 | 129 | 134 | 143 | 147 |
| **4.0** | **252** | 177 | 184 | 191 | 197 | 204 | 211 | 218 | 225 | 232 | 239 | 246 | 259 | 266 |
| **4.5** | **393** | 286 | 295 | 305 | 315 | 325 | 334 | 344 | 354 | 364 | 373 | 383 | 403 | 412 |
| **5.0** | **567** | 421 | 434 | 448 | 461 | 474 | 487 | 501 | 514 | 527 | 540 | 553 | 580 | 593 |
| **5.5** | **781** | 586 | 604 | 621 | 639 | 657 | 674 | 692 | 710 | 727 | 745 | 763 | 798 | 816 |
| **6.0** | **1039** | 785 | 808 | 831 | 854 | 877 | 900 | 923 | 947 | 970 | 993 | 1016 | 1062 | 1086 |
| **6.5** | **1337** | 1016 | 1045 | 1074 | 1104 | 1133 | 1162 | 1191 | 1221 | 1250 | 1279 | 1308 | 1366 | 1396 |
| **7.0** | **1667** | 1272 | 1308 | 1344 | 1380 | 1416 | 1452 | 1488 | 1524 | 1560 | 1595 | 1631 | 1702 | 1738 |
| **7.5** | **2000** | 1532 | 1575 | 1617 | 1660 | 1702 | 1745 | 1788 | 1830 | 1872 | 1915 | 1957 | 2042 | 2084 |
| **8.0** | **2316** | 1779 | 1828 | 1877 | 1926 | 1975 | 2024 | 2073 | 2121 | 2170 | 2219 | 2268 | 2365 | 2414 |
| **8.5** | **2596** | 1997 | 2052 | 2106 | 2161 | 2215 | 2270 | 2324 | 2378 | 2433 | 2487 | 2541 | 2650 | 2704 |
| **9.0** | **2828** | 2177 | 2236 | 2296 | 2355 | 2414 | 2473 | 2532 | 2591 | 2650 | 2710 | 2769 | 2887 | 2946 |
| **9.5** | **3018** | 2325 | 2388 | 2451 | 2514 | 2577 | 2640 | 2703 | 2766 | 2829 | 2892 | 2955 | 3081 | 3144 |
| **10.0** | **3169** | 2442 | 2509 | 2575 | 2641 | 2707 | 2773 | 2839 | 2905 | 2971 | 3037 | 3103 | 3234 | 3299 |
| **10.5** | **3280** | 2530 | 2599 | 2667 | 2735 | 2804 | 2872 | 2940 | 3009 | 3077 | 3145 | 3213 | 3347 | 3414 |
| **11.0** | **3371** | 2601 | 2671 | 2741 | 2812 | 2882 | 2952 | 3022 | 3092 | 3162 | 3232 | 3301 | 3437 | 3502 |
| **11.5** | **3448** | 2666 | 2737 | 2809 | 2881 | 2953 | 3025 | 3096 | 3168 | 3240 | 3309 | 3379 | 3511 | 3573 |
| **12.0** | **3522** | 2733 | 2807 | 2880 | 2954 | 3027 | 3100 | 3173 | 3246 | 3319 | 3387 | 3454 | 3582 | 3642 |
| **12.5** | **3580** | 2790 | 2864 | 2939 | 3014 | 3089 | 3163 | 3236 | 3310 | 3383 | 3449 | 3515 | 3637 | 3694 |
| **13.0** | **3611** | 2824 | 2900 | 2976 | 3052 | 3128 | 3201 | 3273 | 3346 | 3419 | 3483 | 3547 | 3665 | 3720 |
| **13.5** | **3617** | 2843 | 2919 | 2995 | 3070 | 3146 | 3218 | 3289 | 3361 | 3433 | 3494 | 3555 | 3668 | 3719 |
| **14.0** | **3623** | 2858 | 2934 | 3010 | 3085 | 3161 | 3232 | 3303 | 3373 | 3444 | 3504 | 3563 | 3673 | 3723 |
| **14.5** | **3631** | 2876 | 2952 | 3028 | 3104 | 3180 | 3250 | 3319 | 3389 | 3458 | 3516 | 3574 | 3681 | 3730 |
| **15.0** | **3645** | 2900 | 2975 | 3051 | 3126 | 3202 | 3269 | 3337 | 3404 | 3472 | 3530 | 3588 | 3694 | 3743 |
| **15.5** | **3669** | 2934 | 3010 | 3085 | 3160 | 3235 | 3301 | 3368 | 3434 | 3500 | 3556 | 3612 | 3716 | 3764 |
| **16.0** | **3701** | 2980 | 3055 | 3130 | 3205 | 3280 | 3344 | 3409 | 3474 | 3538 | 3592 | 3647 | 3747 | 3793 |
| **16.5** | **3738** | 3033 | 3108 | 3182 | 3256 | 3330 | 3393 | 3456 | 3519 | 3582 | 3634 | 3686 | 3781 | 3824 |
| **17.0** | **3777** | 3094 | 3167 | 3239 | 3312 | 3385 | 3446 | 3507 | 3568 | 3630 | 3679 | 3728 | 3818 | 3858 |
| **17.5** | **3796** | 3160 | 3230 | 3299 | 3369 | 3438 | 3495 | 3551 | 3608 | 3664 | 3708 | 3752 | 3831 | 3866 |
| **18.0** | **3843** | 3239 | 3307 | 3374 | 3441 | 3509 | 3562 | 3616 | 3670 | 3723 | 3763 | 3803 | 3874 | 3906 |
| **18.5** | **3890** | 3324 | 3389 | 3455 | 3520 | 3585 | 3635 | 3684 | 3734 | 3784 | 3819 | 3855 | 3917 | 3944 |
| **19.0** | **3922** | 3408 | 3468 | 3527 | 3587 | 3646 | 3691 | 3736 | 3781 | 3826 | 3858 | 3890 | 3946 | 3970 |
| **19.5** | **3963** | 3494 | 3550 | 3606 | 3662 | 3718 | 3758 | 3798 | 3839 | 3879 | 3907 | 3935 | 3982 | 4002 |
| **20.0** | **3997** | 3580 | 3632 | 3684 | 3736 | 3788 | 3823 | 3858 | 3893 | 3928 | 3951 | 3974 | 4013 | 4029 |

## 7.17 Ct Values, Sound Optimized Mode SO6

| Air density kg/m³ | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Wind speed [m/s]** | **1.225** | **0.950** | **0.975** | **1.000** | **1.025** | **1.050** | **1.075** | **1.100** | **1.125** | **1.150** | **1.175** | **1.200** | **1.250** | **1.275** |
| **3.0** | **0.885** | 0.877 | 0.878 | 0.880 | 0.881 | 0.883 | 0.883 | 0.884 | 0.884 | 0.884 | 0.884 | 0.884 | 0.884 | 0.884 |
| **3.5** | **0.844** | 0.844 | 0.844 | 0.844 | 0.844 | 0.844 | 0.844 | 0.844 | 0.844 | 0.844 | 0.844 | 0.844 | 0.844 | 0.844 |
| **4.0** | **0.806** | 0.805 | 0.805 | 0.805 | 0.805 | 0.805 | 0.805 | 0.805 | 0.806 | 0.806 | 0.806 | 0.806 | 0.805 | 0.805 |
| **4.5** | **0.795** | 0.794 | 0.795 | 0.795 | 0.796 | 0.796 | 0.796 | 0.796 | 0.796 | 0.796 | 0.795 | 0.795 | 0.795 | 0.795 |
| **5.0** | **0.789** | 0.793 | 0.793 | 0.792 | 0.792 | 0.792 | 0.791 | 0.791 | 0.791 | 0.790 | 0.790 | 0.790 | 0.789 | 0.789 |
| **5.5** | **0.792** | 0.790 | 0.790 | 0.790 | 0.790 | 0.790 | 0.790 | 0.791 | 0.791 | 0.791 | 0.791 | 0.792 | 0.792 | 0.792 |
| **6.0** | **0.793** | 0.790 | 0.790 | 0.790 | 0.791 | 0.791 | 0.791 | 0.792 | 0.792 | 0.792 | 0.792 | 0.793 | 0.793 | 0.794 |
| **6.5** | **0.776** | 0.774 | 0.774 | 0.774 | 0.774 | 0.775 | 0.775 | 0.775 | 0.775 | 0.776 | 0.776 | 0.776 | 0.777 | 0.777 |
| **7.0** | **0.740** | 0.738 | 0.739 | 0.739 | 0.739 | 0.739 | 0.739 | 0.739 | 0.740 | 0.740 | 0.740 | 0.740 | 0.741 | 0.741 |
| **7.5** | **0.692** | 0.690 | 0.691 | 0.691 | 0.691 | 0.691 | 0.691 | 0.691 | 0.692 | 0.692 | 0.692 | 0.692 | 0.692 | 0.692 |
| **8.0** | **0.639** | 0.637 | 0.637 | 0.638 | 0.638 | 0.638 | 0.638 | 0.638 | 0.638 | 0.639 | 0.639 | 0.639 | 0.639 | 0.639 |
| **8.5** | **0.575** | 0.573 | 0.573 | 0.574 | 0.574 | 0.574 | 0.574 | 0.574 | 0.574 | 0.574 | 0.574 | 0.574 | 0.575 | 0.575 |
| **9.0** | **0.505** | 0.504 | 0.504 | 0.504 | 0.504 | 0.504 | 0.504 | 0.504 | 0.504 | 0.504 | 0.504 | 0.504 | 0.505 | 0.505 |
| **9.5** | **0.442** | 0.442 | 0.442 | 0.442 | 0.442 | 0.442 | 0.442 | 0.442 | 0.442 | 0.442 | 0.442 | 0.442 | 0.443 | 0.443 |
| **10.0** | **0.387** | 0.386 | 0.386 | 0.387 | 0.387 | 0.387 | 0.387 | 0.387 | 0.387 | 0.387 | 0.387 | 0.387 | 0.387 | 0.387 |
| **10.5** | **0.338** | 0.338 | 0.338 | 0.338 | 0.338 | 0.338 | 0.338 | 0.338 | 0.338 | 0.338 | 0.338 | 0.338 | 0.338 | 0.338 |
| **11.0** | **0.297** | 0.297 | 0.297 | 0.297 | 0.297 | 0.297 | 0.297 | 0.297 | 0.297 | 0.297 | 0.297 | 0.297 | 0.297 | 0.296 |
| **11.5** | **0.262** | 0.262 | 0.263 | 0.263 | 0.263 | 0.263 | 0.263 | 0.263 | 0.263 | 0.263 | 0.263 | 0.262 | 0.262 | 0.261 |
| **12.0** | **0.233** | 0.235 | 0.235 | 0.235 | 0.235 | 0.235 | 0.235 | 0.235 | 0.235 | 0.235 | 0.234 | 0.234 | 0.233 | 0.232 |
| **12.5** | **0.208** | 0.210 | 0.210 | 0.210 | 0.210 | 0.210 | 0.210 | 0.210 | 0.210 | 0.210 | 0.210 | 0.209 | 0.207 | 0.207 |
| **13.0** | **0.186** | 0.188 | 0.188 | 0.188 | 0.188 | 0.188 | 0.188 | 0.188 | 0.188 | 0.188 | 0.187 | 0.186 | 0.185 | 0.184 |
| **13.5** | **0.166** | 0.168 | 0.168 | 0.168 | 0.168 | 0.168 | 0.168 | 0.168 | 0.168 | 0.168 | 0.167 | 0.166 | 0.165 | 0.164 |
| **14.0** | **0.148** | 0.151 | 0.151 | 0.151 | 0.151 | 0.151 | 0.151 | 0.151 | 0.151 | 0.150 | 0.150 | 0.149 | 0.147 | 0.146 |
| **14.5** | **0.134** | 0.137 | 0.137 | 0.137 | 0.137 | 0.137 | 0.136 | 0.136 | 0.136 | 0.136 | 0.135 | 0.134 | 0.133 | 0.132 |
| **15.0** | **0.121** | 0.124 | 0.124 | 0.124 | 0.124 | 0.124 | 0.124 | 0.123 | 0.123 | 0.123 | 0.122 | 0.122 | 0.120 | 0.119 |
| **15.5** | **0.110** | 0.114 | 0.114 | 0.114 | 0.114 | 0.114 | 0.113 | 0.113 | 0.113 | 0.112 | 0.112 | 0.111 | 0.110 | 0.109 |
| **16.0** | **0.101** | 0.105 | 0.105 | 0.105 | 0.105 | 0.105 | 0.104 | 0.104 | 0.104 | 0.103 | 0.103 | 0.102 | 0.101 | 0.100 |
| **16.5** | **0.094** | 0.098 | 0.098 | 0.097 | 0.097 | 0.097 | 0.097 | 0.096 | 0.096 | 0.095 | 0.095 | 0.094 | 0.093 | 0.092 |
| **17.0** | **0.087** | 0.091 | 0.091 | 0.091 | 0.091 | 0.090 | 0.090 | 0.090 | 0.089 | 0.089 | 0.088 | 0.087 | 0.086 | 0.085 |
| **17.5** | **0.080** | 0.086 | 0.086 | 0.085 | 0.085 | 0.085 | 0.084 | 0.084 | 0.083 | 0.083 | 0.082 | 0.081 | 0.080 | 0.079 |
| **18.0** | **0.075** | 0.081 | 0.081 | 0.080 | 0.080 | 0.080 | 0.079 | 0.078 | 0.078 | 0.077 | 0.077 | 0.076 | 0.074 | 0.074 |
| **18.5** | **0.070** | 0.077 | 0.076 | 0.076 | 0.076 | 0.075 | 0.075 | 0.074 | 0.073 | 0.073 | 0.072 | 0.071 | 0.070 | 0.069 |
| **19.0** | **0.065** | 0.073 | 0.072 | 0.072 | 0.071 | 0.070 | 0.070 | 0.069 | 0.068 | 0.068 | 0.067 | 0.066 | 0.065 | 0.064 |
| **19.5** | **0.061** | 0.069 | 0.068 | 0.068 | 0.067 | 0.067 | 0.066 | 0.065 | 0.065 | 0.064 | 0.063 | 0.062 | 0.061 | 0.060 |
| **20.0** | **0.058** | 0.066 | 0.065 | 0.064 | 0.064 | 0.063 | 0.062 | 0.062 | 0.061 | 0.060 | 0.059 | 0.059 | 0.057 | 0.056 |

## 7.18 Sound Curves, Sound Optimized Mode SO6

| Sound Power Level at Hub Height | |
|---|---|
| **Conditions for Sound Power Level:** | **Measurement standard IEC 61400-11 ed. 3**<br>**Maximum turbulence at hub height: 30%**<br>**Inflow angle (vertical): 0 ±2°**<br>**Air density: 1.225 kg/m$^3$** |
| **Wind speed at hub height [m/s]** | **Sound Power Level at Hub Height [dBA]**<br>**Sound Optimized Mode SO6 (Blades with serrated trailing edge)** |
| 3 | 91.3 |
| 4 | 91.5 |
| 5 | 93.9 |
| 6 | 96.9 |
| 7 | 97.8 |
| 8 | 98.0 |
| 9 | 98.0 |
| 10 | 98.0 |
| 11 | 98.0 |
| 12 | 98.0 |
| 13 | 98.0 |
| 14 | 98.0 |
| 15 | 98.0 |
| 16 | 98.0 |
| 17 | 98.0 |
| 18 | 98.0 |
| 19 | 98.0 |
| 20 | 98.0 |

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# RPM Curves

## EnVentus™

## V150-6.0 MW 50/60 Hz

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# 1 Introduction

This document contains the RPM curves as a function of wind speed for the following turbine configurations:

- V150 – 6.0MW

Note:

The RPM curves in this document are based on an early technical maturity on the V150-6.0MW design, and may therefore change, as the technical maturity increases.

## 2 Average rotor speed vs. wind speed

| | V150 |
|---|---|
| | 6.0 MW |
| Wind Speed [m/s] | Speed [RPM] |
| **3.0** | 4,82 |
| **3.5** | 4,90 |
| **4.0** | 4,93 |
| **4.5** | 5,23 |
| **5.0** | 5,74 |
| **5.5** | 6,30 |
| **6.0** | 6,88 |
| **6.5** | 7,47 |
| **7.0** | 8,06 |
| **7.5** | 8,64 |
| **8.0** | 9,22 |
| **8.5** | 9,76 |
| **9.0** | 10,04 |
| **9.5** | 10,10 |
| **10.0** | 10,12 |
| **10.5** | 10,12 |
| **11.0** | 10,11 |
| **11.5** | 10,12 |
| **12.0** | 10,12 |
| **12.5** | 10,12 |
| **13.0** | 10,12 |
| **13.5** | 10,12 |
| **14.0** | 10,12 |
| **14.5** | 10,12 |
| **15.0** | 10,12 |
| **15.5** | 10,12 |
| **16.0** | 10,12 |
| **16.5** | 10,12 |
| **17.0** | 10,12 |
| **17.5** | 10,09 |
| **18.0** | 9,81 |
| **18.5** | 9,51 |
| **19.0** | 9,22 |
| **19.5** | 8,91 |
| **20.0** | 8,61 |
| **20.5** | 8,31 |
| **21.0** | 8,00 |
| **21.5** | 7,62 |
| **22.0** | 7,27 |
| **22.5** | 6,91 |
| **23.0** | 6,60 |
| **23.5** | 6,35 |
| **24.0** | 6,07 |
| **24.5** | 5,88 |
| **25.0** | 5,88 |

| | V150 | | | | | |
|---|---|---|---|---|---|---|
| | | | | | | |
| | **SO0** (104dB) | **Mode SO2** (101dB) | **Mode SO3** (100dB) | **Mode SO4** (100dB) | **Mode SO5** (99dB) | **Mode SO6** (98dB) |
| Wind Speed [m/s] | Speed [RPM] | Speed [RPM] | Speed [RPM] | Speed [RPM] | Speed [RPM] | Speed [RPM] |
| **3.0** | 4.89 | 4.89 | 4.89 | 4.89 | 4.89 | 4.89 |
| **3.5** | 4.91 | 4.91 | 4.91 | 4.91 | 4.91 | 4.91 |
| **4.0** | 5.01 | 5.01 | 5.01 | 5.01 | 5.01 | 5.01 |
| **4.5** | 5.49 | 5.51 | 5.51 | 5.51 | 5.51 | 5.51 |
| **5.0** | 6.03 | 6.06 | 6.06 | 6.06 | 6.06 | 6.06 |
| **5.5** | 6.63 | 6.63 | 6.63 | 6.63 | 6.63 | 6.63 |
| **6.0** | 7.25 | 7.25 | 7.25 | 7.25 | 7.18 | 7.13 |
| **6.5** | 7.86 | 7.86 | 7.86 | 7.79 | 7.57 | 7.34 |
| **7.0** | 8.48 | 8.43 | 8.37 | 8.23 | 7.82 | 7.41 |
| **7.5** | 9.10 | 8.94 | 8.64 | 8.34 | 7.89 | 7.43 |
| **8.0** | 9.60 | 9.23 | 8.75 | 8.34 | 7.89 | 7.43 |
| **8.5** | 9.83 | 9.33 | 8.80 | 8.34 | 7.89 | 7.43 |
| **9.0** | 9.87 | 9.33 | 8.80 | 8.34 | 7.89 | 7.43 |
| **9.5** | 9.87 | 9.33 | 8.80 | 8.34 | 7.89 | 7.43 |
| **10.0** | 9.87 | 9.33 | 8.80 | 8.34 | 7.89 | 7.43 |
| **10.5** | 9.87 | 9.35 | 8.80 | 8.34 | 7.89 | 7.43 |
| **11.0** | 9.85 | 9.35 | 8.80 | 8.37 | 7.89 | 7.43 |
| **11.5** | 9.87 | 9.33 | 8.80 | 8.37 | 7.91 | 7.43 |
| **12.0** | 9.87 | 9.33 | 8.80 | 8.37 | 7.91 | 7.43 |
| **12.5** | 9.87 | 9.33 | 8.80 | 8.37 | 7.91 | 7.43 |
| **13.0** | 9.87 | 9.33 | 8.80 | 8.37 | 7.91 | 7.45 |
| **13.5** | 9.87 | 9.33 | 8.80 | 8.37 | 7.91 | 7.45 |
| **14.0** | 9.87 | 9.33 | 8.80 | 8.34 | 7.91 | 7.45 |
| **14.5** | 9.87 | 9.33 | 8.80 | 8.37 | 7.91 | 7.45 |
| **15.0** | 9.87 | 9.33 | 8.80 | 8.34 | 7.91 | 7.45 |
| **15.5** | 9.87 | 9.33 | 8.80 | 8.34 | 7.91 | 7.45 |
| **16.0** | 9.87 | 9.33 | 8.80 | 8.37 | 7.91 | 7.45 |
| **16.5** | 9.87 | 9.33 | 8.80 | 8.37 | 7.91 | 7.45 |
| **17.0** | 9.87 | 9.33 | 8.80 | 8.37 | 7.91 | 7.45 |
| **17.5** | 9.87 | 9.33 | 8.80 | 8.37 | 7.91 | 7.45 |
| **18.0** | 9.81 | 9.33 | 8.80 | 8.37 | 7.91 | 7.45 |
| **18.5** | 9.65 | 9.33 | 8.80 | 8.37 | 7.91 | 7.45 |
| **19.0** | 9.37 | 9.23 | 8.80 | 8.37 | 7.91 | 7.45 |
| **19.5** | 9.10 | 9.05 | 8.78 | 8.37 | 7.91 | 7.45 |
| **20.0** | 8.80 | 8.78 | 8.69 | 8.34 | 7.91 | 7.45 |

## 3 10 min Average/1 sec max rotor speed vs. wind speed in Idle

| | V150 | V150 |
|---|---|---|
| Wind Speed [m/s] | Average Speed [RPM] | Max Speed [RPM |
| **0.0** | 0,00 | 0,00 |
| **1.0** | 0,09 | 0,12 |
| **2.0** | 0,18 | 0,25 |
| **3.0** | 0,28 | 0,37 |
| **4.0** | 0,37 | 0,50 |
| **5.0** | 0,46 | 0,62 |
| **6.0** | 0,55 | 0,74 |
| **7.0** | 0,64 | 0,87 |
| **8.0** | 0,74 | 0,99 |
| **9.0** | 0,83 | 1,12 |
| **10.0** | 0,92 | 1,24 |
| **11.0** | 1,01 | 1,36 |
| **12.0** | 1,10 | 1,49 |
| **13.0** | 1,20 | 1,61 |
| **14.0** | 1,29 | 1,74 |
| **15.0** | 1,38 | 1,86 |
| **16.0** | 1,47 | 1,98 |
| **17.0** | 1,56 | 2,11 |
| **18.0** | 1,66 | 2,23 |
| **19.0** | 1,75 | 2,36 |
| **20.0** | 1,84 | 2,48 |
| **21.0** | 1,93 | 2,60 |
| **22.0** | 2,02 | 2,73 |
| **23.0** | 2,12 | 2,85 |
| **24.0** | 2,21 | 2,98 |
| **25.0** | 2,30 | 3,10 |

Note: Values for V150 are based on extrapolations from values measured on V117, V126 and V136.

## 4 Transition time from Production to Idle

Based on numerous simulations, the duration from a shutdown (pause) command is sent to the turbine and until the turbine reaches steady state Idle rotor speed below 2 RPM, has been determined to be between 20 and 40 seconds.

Actual timing is dependent on windspeed, turbulence etc., but not significantly dependent on the rotor size

## 5 General Reservations, Notes and Disclaimers

- 
- The RPM Curves described in this document apply to the current version of the V150-6.0MW wind turbine. Updated versions of the V150-6.0MW wind turbine, which may be manufactured in the future, may differ from these performance specifications. In the event that Vestas supplies an updated version of the V150-6.0MW wind turbine, Vestas will provide updated RPM Curves applicable to the updated version.
- This document, RPM Curves, is not an offer for sale, and does not contain any guarantee, warranty and/or verification of the power curve and sound (including, without limitation, the power curve and sound verification method). Any guarantee, warranty and/or verification of the power curve and sound (including, without limitation, the power curve and sound verification method) must be agreed to separately in writing.

DOCUMENT: [0056-6108] VER 04

DESCRIPTION: 3MW RPM curves

RESTRICTED



# 3MW RPM curves

## V105 – 3.45/3.6MW
## V112 – 3.45/3.6MW
## V117 – 3.45/3.6MW
## V126 – 3.45MW Low Torque
## V126 – 3.45/3.6MW High Torque
## V136 – 3.45/3.6MW

# Table of Contents

# 1. Introduction

This document contains the RPM curves as a function of wind speed for the following 3MW turbine configurations:

- V105 – 3.45/3.6MW
- V112 – 3.45/3.6MW
- V117 – 3.45/3.6MW
- V126 – 3.45MW Low Torque
- V126 – 3.45/3.6MW High Torque
- V136 – 3.45/3.6MW

## 2. Average rotor speed vs. wind speed

| | V105 | V105 | V112 | V112 | V117 | V117 | V126 | V126 | V126 | V126 | V126 | V136 | V136 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 3.45MW | 3.6MW | 3.45MW | 3.6MW | 3.45MW | 3.6MW | 3.45MW | 3.45MW | 3.6MW | 3.45MW | 3.45MW | 3.45MW | 3.6MW |
| | | | | | | | Low Torque | High Torque | High Torque | High Torque | High Torque | | |
| | Mode 0 | PO1 | Mode 0 | PO1 | Mode 0 | PO1 | Mode 0 | Mode 0 | PO1 | SO1 | SO2 | Mode 0 | PO1 |
| Wind Speed [m/s] | Speed [RPM] | Speed [RPM] | Speed [RPM] | Speed [RPM] | Speed [RPM] | Speed [RPM] | Speed [RPM] | Speed [RPM] | Speed [RPM] | Speed [RPM] | Speed [RPM] | Speed [RPM] | Speed [RPM] |
| **3.0** | 7.77 | 7.77 | 8.02 | 8.02 | 6.69 | 6.69 | 6.18 | 5.93 | 5.93 | 5.93 | 5.93 | 5.56 | 5.56 |
| **3.5** | 8.33 | 8.33 | 8.05 | 8.05 | 6.69 | 6.69 | 6.18 | 5.93 | 5.93 | 5.93 | 5.93 | 5.56 | 5.56 |
| **4.0** | 8.33 | 8.33 | 8.05 | 8.05 | 6.69 | 6.69 | 6.18 | 5.93 | 5.93 | 5.93 | 5.93 | 5.57 | 5.57 |
| **4.5** | 8.33 | 8.33 | 8.05 | 8.05 | 6.91 | 6.91 | 6.28 | 6.18 | 6.18 | 6.18 | 6.18 | 5.97 | 5.97 |
| **5.0** | 8.34 | 8.34 | 8.13 | 8.13 | 7.62 | 7.62 | 6.84 | 6.83 | 6.83 | 6.83 | 6.83 | 6.61 | 6.61 |
| **5.5** | 8.68 | 8.68 | 8.68 | 8.68 | 8.38 | 8.38 | 7.50 | 7.49 | 7.49 | 7.49 | 7.49 | 7.25 | 7.25 |
| **6.0** | 9.38 | 9.38 | 9.44 | 9.44 | 9.12 | 9.12 | 8.17 | 8.17 | 8.17 | 8.17 | 8.15 | 7.91 | 7.91 |
| **6.5** | 10.14 | 10.14 | 10.22 | 10.22 | 9.89 | 9.89 | 8.85 | 8.84 | 8.84 | 8.84 | 8.83 | 8.56 | 8.56 |
| **7.0** | 10.94 | 10.94 | 11.01 | 11.01 | 10.66 | 10.68 | 9.51 | 9.49 | 9.49 | 9.49 | 9.35 | 9.21 | 9.21 |
| **7.5** | 11.72 | 11.72 | 11.80 | 11.80 | 11.38 | 11.38 | 10.13 | 10.13 | 10.13 | 10.11 | 9.58 | 9.87 | 9.87 |
| **8.0** | 12.49 | 12.49 | 12.57 | 12.57 | 12.16 | 12.16 | 10.86 | 10.84 | 10.84 | 10.65 | 9.69 | 10.51 | 10.51 |
| **8.5** | 13.22 | 13.25 | 13.28 | 13.31 | 12.90 | 12.90 | 11.52 | 11.43 | 11.49 | 10.88 | 9.76 | 11.12 | 11.12 |
| **9.0** | 13.66 | 13.77 | 13.70 | 13.81 | 13.49 | 13.55 | 12.16 | 11.73 | 11.94 | 10.96 | 9.82 | 11.52 | 11.52 |
| **9.5** | 13.83 | 14.00 | 13.84 | 14.01 | 13.79 | 13.94 | 12.75 | 11.83 | 12.12 | 10.97 | 9.87 | 11.65 | 11.65 |
| **10.0** | 13.85 | 14.04 | 13.85 | 14.04 | 13.84 | 14.02 | 13.18 | 11.82 | 12.13 | 10.99 | 9.91 | 11.65 | 11.65 |
| **10.5** | 13.84 | 14.03 | 13.84 | 14.02 | 13.83 | 14.02 | 13.37 | 11.82 | 12.13 | 11.02 | 9.94 | 11.67 | 11.66 |
| **11.0** | 13.83 | 14.01 | 13.83 | 14.01 | 13.84 | 14.02 | 13.41 | 11.83 | 12.13 | 11.08 | 9.97 | 11.67 | 11.67 |
| **11.5** | 13.82 | 14.01 | 13.84 | 14.01 | 13.84 | 14.02 | 13.42 | 11.83 | 12.14 | 11.13 | 9.98 | 11.67 | 11.67 |
| **12.0** | 13.85 | 14.02 | 13.84 | 14.02 | 13.85 | 14.04 | 13.42 | 11.83 | 12.14 | 11.19 | 9.98 | 11.67 | 11.67 |
| **12.5** | 13.85 | 14.04 | 13.85 | 14.03 | 13.85 | 14.04 | 13.42 | 11.83 | 12.15 | 11.25 | 9.97 | 11.67 | 11.67 |
| **13.0** | 13.86 | 14.04 | 13.85 | 14.04 | 13.85 | 14.04 | 13.42 | 11.83 | 12.15 | 11.30 | 9.97 | 11.67 | 11.67 |
| **13.5** | 13.86 | 14.04 | 13.85 | 14.04 | 13.85 | 14.04 | 13.42 | 11.83 | 12.14 | 11.34 | 9.97 | 11.67 | 11.67 |
| **14.0** | 13.85 | 14.05 | 13.85 | 14.04 | 13.85 | 14.04 | 13.42 | 11.83 | 12.14 | 11.36 | 9.97 | 11.67 | 11.67 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **14.5** | 13.85 | 14.05 | 13.85 | 14.04 | 13.85 | 14.04 | 13.42 | 11.83 | 12.14 | 11.38 | 9.96 | 11.67 | 11.67 |
| **15.0** | 13.85 | 14.04 | 13.85 | 14.04 | 13.85 | 14.04 | 13.42 | 11.83 | 12.14 | 11.40 | 9.96 | 11.67 | 11.67 |
| **15.5** | 13.85 | 14.04 | 13.85 | 14.04 | 13.85 | 14.04 | 13.42 | 11.83 | 12.14 | 11.44 | 9.96 | 11.67 | 11.67 |
| **16.0** | 13.85 | 14.04 | 13.85 | 14.04 | 13.85 | 14.04 | 13.42 | 11.83 | 12.14 | 11.49 | 9.96 | 11.67 | 11.67 |
| **16.5** | 13.85 | 14.04 | 13.85 | 14.04 | 13.85 | 14.04 | 13.42 | 11.83 | 12.14 | 11.54 | 9.96 | 11.67 | 11.67 |
| **17.0** | 13.85 | 14.04 | 13.85 | 14.04 | 13.85 | 14.04 | 13.42 | 11.83 | 12.14 | 11.57 | 9.96 | 11.67 | 11.67 |
| **17.5** | 13.85 | 14.04 | 13.85 | 14.04 | 13.85 | 14.04 | 13.42 | 11.83 | 12.14 | 11.59 | 9.96 | 11.67 | 11.67 |
| **18.0** | 13.85 | 14.04 | 13.85 | 14.04 | 13.85 | 14.04 | 13.42 | 11.83 | 12.14 | 11.60 | 9.96 | 11.67 | 11.67 |
| **18.5** | 13.85 | 14.04 | 13.85 | 14.04 | 13.85 | 14.04 | 13.42 | 11.83 | 12.14 | 11.61 | 9.96 | 11.67 | 11.67 |
| **19.0** | 13.85 | 14.04 | 13.85 | 14.04 | 13.85 | 14.04 | 13.42 | 11.83 | 12.14 | 11.61 | 9.97 | 11.67 | 11.67 |
| **19.5** | 13.85 | 14.04 | 13.85 | 14.04 | 13.85 | 14.04 | 13.42 | 11.83 | 12.15 | 11.64 | 9.96 | 11.67 | 11.67 |
| **20.0** | 13.85 | 14.04 | 13.85 | 14.04 | 13.85 | 14.04 | 13.42 | 11.83 | 12.15 | 11.68 | 9.96 | 11.67 | 11.67 |
| **20.5** | 13.85 | 14.04 | 13.85 | 14.04 | 13.85 | 14.04 | 13.42 | 11.83 | 12.15 | 11.71 | 9.96 | 11.67 | 11.67 |
| **21.0** | 13.85 | 14.04 | 13.85 | 14.04 | 13.85 | 14.04 | 13.42 | 11.83 | 12.15 | 11.74 | 9.96 | 11.67 | 11.67 |
| **21.5** | 13.85 | 14.04 | 13.85 | 14.04 | 13.85 | 14.04 | 13.42 | 11.83 | 12.14 | 11.76 | 9.97 | 11.67 | 11.67 |
| **22.0** | 13.85 | 14.04 | 13.85 | 14.04 | 13.85 | 14.04 | 13.42 | 11.83 | 12.14 | 11.79 | 9.97 | 11.67 | 11.67 |
| **22.5** | 13.85 | 14.04 | 13.85 | 14.04 | 13.85 | 14.04 | 13.42 | 11.83 | 12.14 | 11.81 | 9.97 | 11.67 | 11.67 |
| **23.0** | 13.86 | 14.05 | 13.85 | 14.04 | 13.86 | 14.05 | - | 11.83 | 12.15 | 11.82 | 9.97 | - | - |
| **23.5** | 13.86 | 14.05 | 13.85 | 14.04 | 13.86 | 14.05 | - | 11.83 | 12.15 | 11.83 | 9.97 | - | - |
| **24.0** | 13.86 | 14.04 | 13.86 | 14.04 | 13.86 | 14.05 | - | 11.83 | 12.15 | 11.84 | 9.97 | - | - |
| **24.5** | 13.86 | 14.04 | 13.86 | 14.04 | 13.86 | 14.05 | - | 11.83 | 12.15 | 11.84 | 9.97 | - | - |
| **25.0** | 13.86 | 14.04 | 13.86 | 14.04 | 13.86 | 14.05 | - | 11.83 | 12.15 | 11.84 | 9.97 | - | - |

# 3. Average generator speed vs. wind speed

| | V105 | V105 | V112 | V112 | V117 | V117 | V126 | V126 | V126 | V126 | V126 | V136 | V136 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 3.45MW | 3.6MW | 3.45MW | 3.6MW | 3.45MW | 3.6MW | 3.45MW | 3.45MW | 3.6MW | 3.45MW | 3.45MW | 3.45MW | 3.6MW |
| | | | | | | | Low Torque | High Torque | High Torque | High Torque | High Torque | | |
| | Mode 0 | PO1 | Mode 0 | PO1 | Mode 0 | PO1 | Mode 0 | Mode 0 | PO1 | SO1 | SO2 | Mode 0 | PO1 |
| Wind Speed [m/s] | Speed [RPM] | Speed [RPM] | Speed [RPM] | Speed [RPM] | Speed [RPM] | Speed [RPM] | Speed [RPM] | Speed [RPM] | Speed [RPM] | Speed [RPM] | Speed [RPM] | Speed [RPM] | Speed [RPM] |
| **3.0** | 814 | 814 | 840 | 840 | 700 | 700 | 700 | 747 | 747 | 747 | 747 | 700 | 700 |
| **3.5** | 872 | 872 | 843 | 843 | 700 | 700 | 700 | 747 | 747 | 747 | 747 | 700 | 700 |
| **4.0** | 872 | 872 | 843 | 843 | 700 | 700 | 700 | 747 | 747 | 747 | 747 | 702 | 702 |
| **4.5** | 872 | 872 | 843 | 843 | 724 | 724 | 712 | 779 | 779 | 779 | 779 | 752 | 752 |
| **5.0** | 873 | 873 | 851 | 851 | 798 | 798 | 775 | 860 | 860 | 860 | 860 | 833 | 833 |
| **5.5** | 909 | 909 | 909 | 909 | 877 | 877 | 850 | 944 | 944 | 944 | 944 | 914 | 914 |
| **6.0** | 982 | 982 | 988 | 988 | 955 | 955 | 926 | 1029 | 1029 | 1029 | 1027 | 997 | 997 |
| **6.5** | 1062 | 1062 | 1070 | 1070 | 1036 | 1036 | 1003 | 1114 | 1114 | 1114 | 1112 | 1079 | 1079 |
| **7.0** | 1145 | 1145 | 1153 | 1153 | 1116 | 1118 | 1078 | 1196 | 1196 | 1196 | 1178 | 1161 | 1161 |
| **7.5** | 1227 | 1227 | 1235 | 1235 | 1192 | 1192 | 1148 | 1276 | 1276 | 1274 | 1207 | 1243 | 1243 |
| **8.0** | 1308 | 1308 | 1316 | 1316 | 1273 | 1273 | 1230 | 1366 | 1366 | 1342 | 1221 | 1324 | 1324 |
| **8.5** | 1384 | 1387 | 1390 | 1394 | 1351 | 1351 | 1305 | 1440 | 1448 | 1370 | 1230 | 1401 | 1401 |
| **9.0** | 1430 | 1442 | 1434 | 1446 | 1412 | 1419 | 1378 | 1478 | 1504 | 1380 | 1237 | 1452 | 1451 |
| **9.5** | 1448 | 1466 | 1449 | 1467 | 1444 | 1459 | 1445 | 1490 | 1527 | 1382 | 1243 | 1468 | 1468 |
| **10.0** | 1450 | 1470 | 1450 | 1470 | 1449 | 1468 | 1493 | 1489 | 1529 | 1384 | 1248 | 1468 | 1468 |
| **10.5** | 1449 | 1469 | 1449 | 1468 | 1448 | 1468 | 1515 | 1489 | 1528 | 1388 | 1252 | 1470 | 1469 |
| **11.0** | 1448 | 1467 | 1448 | 1467 | 1449 | 1468 | 1519 | 1490 | 1528 | 1396 | 1256 | 1470 | 1470 |
| **11.5** | 1447 | 1467 | 1449 | 1467 | 1449 | 1468 | 1520 | 1490 | 1530 | 1402 | 1257 | 1471 | 1471 |
| **12.0** | 1450 | 1468 | 1449 | 1468 | 1450 | 1470 | 1520 | 1491 | 1530 | 1409 | 1257 | 1471 | 1471 |
| **12.5** | 1450 | 1470 | 1450 | 1469 | 1450 | 1470 | 1520 | 1491 | 1531 | 1417 | 1256 | 1470 | 1471 |
| **13.0** | 1451 | 1470 | 1450 | 1470 | 1450 | 1470 | 1520 | 1491 | 1531 | 1424 | 1256 | 1470 | 1470 |
| **13.5** | 1451 | 1470 | 1450 | 1470 | 1450 | 1470 | 1520 | 1490 | 1530 | 1428 | 1256 | 1470 | 1470 |
| **14.0** | 1450 | 1471 | 1450 | 1470 | 1450 | 1470 | 1520 | 1490 | 1530 | 1431 | 1256 | 1470 | 1470 |
| **14.5** | 1450 | 1471 | 1450 | 1470 | 1450 | 1470 | 1520 | 1490 | 1530 | 1433 | 1255 | 1470 | 1470 |
| **15.0** | 1450 | 1470 | 1450 | 1470 | 1450 | 1470 | 1520 | 1490 | 1530 | 1436 | 1255 | 1470 | 1470 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **15.5** | 1450 | 1470 | 1450 | 1470 | 1450 | 1470 | 1520 | 1490 | 1530 | 1441 | 1255 | 1470 | 1470 |
| **16.0** | 1450 | 1470 | 1450 | 1470 | 1450 | 1470 | 1520 | 1490 | 1530 | 1447 | 1255 | 1470 | 1470 |
| **16.5** | 1450 | 1470 | 1450 | 1470 | 1450 | 1470 | 1520 | 1490 | 1530 | 1454 | 1255 | 1470 | 1470 |
| **17.0** | 1450 | 1470 | 1450 | 1470 | 1450 | 1470 | 1520 | 1490 | 1530 | 1458 | 1255 | 1470 | 1470 |
| **17.5** | 1450 | 1470 | 1450 | 1470 | 1450 | 1470 | 1520 | 1490 | 1530 | 1460 | 1255 | 1470 | 1470 |
| **18.0** | 1450 | 1470 | 1450 | 1470 | 1450 | 1470 | 1520 | 1490 | 1530 | 1461 | 1255 | 1470 | 1470 |
| **18.5** | 1450 | 1470 | 1450 | 1470 | 1450 | 1470 | 1520 | 1490 | 1530 | 1462 | 1255 | 1470 | 1470 |
| **19.0** | 1450 | 1470 | 1450 | 1470 | 1450 | 1470 | 1520 | 1491 | 1530 | 1463 | 1256 | 1470 | 1470 |
| **19.5** | 1450 | 1470 | 1450 | 1470 | 1450 | 1470 | 1520 | 1491 | 1531 | 1466 | 1255 | 1470 | 1470 |
| **20.0** | 1450 | 1470 | 1450 | 1470 | 1450 | 1470 | 1520 | 1491 | 1531 | 1471 | 1255 | 1470 | 1470 |
| **20.5** | 1450 | 1470 | 1450 | 1470 | 1450 | 1470 | 1520 | 1491 | 1531 | 1475 | 1255 | 1470 | 1470 |
| **21.0** | 1450 | 1470 | 1450 | 1470 | 1450 | 1470 | 1520 | 1490 | 1531 | 1479 | 1255 | 1470 | 1470 |
| **21.5** | 1450 | 1470 | 1450 | 1470 | 1450 | 1470 | 1520 | 1490 | 1530 | 1482 | 1256 | 1470 | 1470 |
| **22.0** | 1450 | 1470 | 1450 | 1470 | 1450 | 1470 | 1520 | 1490 | 1530 | 1485 | 1256 | 1470 | 1470 |
| **22.5** | 1450 | 1470 | 1450 | 1470 | 1450 | 1470 | 1520 | 1490 | 1530 | 1488 | 1256 | 1470 | 1470 |
| **23.0** | 1451 | 1471 | 1450 | 1470 | 1451 | 1471 | - | 1491 | 1531 | 1489 | 1256 | - | - |
| **23.5** | 1451 | 1471 | 1450 | 1470 | 1451 | 1471 | - | 1491 | 1531 | 1490 | 1256 | - | - |
| **24.0** | 1451 | 1470 | 1451 | 1470 | 1451 | 1471 | - | 1491 | 1531 | 1491 | 1256 | - | - |
| **24.5** | 1451 | 1470 | 1451 | 1470 | 1451 | 1471 | - | 1491 | 1531 | 1491 | 1256 | - | - |
| **25.0** | 1451 | 1470 | 1451 | 1470 | 1451 | 1471 | - | 1491 | 1531 | 1491 | 1256 | - | - |

# 4. Average rotor speed vs. wind speed (HWO)

| | V105 | V105 | V112 | V112 | V117 | V117 | V126 | V126 | V126 | V126 | V126 | V136 | V136 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 3.45MW | 3.6MW | 3.45MW | 3.6MW | 3.45MW | 3.6MW | 3.45MW | 3.45MW | 3.6MW | 3.45MW | 3.45MW | 3.45MW | 3.6MW |
| | | | | | | | Low Torque | High Torque | High Torque | High Torque | High Torque | | |
| | Mode 0 | PO1 | Mode 0 | PO1 | Mode 0 | PO1 | Mode 0 | Mode 0 | PO1 | SO1 | SO2 | Mode 0 | PO1 |
| Wind Speed [m/s] | Speed [RPM] | Speed [RPM] | Speed [RPM] | Speed [RPM] | Speed [RPM] | Speed [RPM] | Speed [RPM] | Speed [RPM] | Speed [RPM] | Speed [RPM] | Speed [RPM] | Speed [RPM] | Speed [RPM] |
| **3.0** | 7.77 | 7.77 | 8.02 | 8.02 | 6.69 | 6.69 | 6.18 | 5.93 | 5.93 | 5.93 | 5.93 | 5.56 | 5.56 |
| **3.5** | 8.33 | 8.33 | 8.05 | 8.05 | 6.69 | 6.69 | 6.18 | 5.93 | 5.93 | 5.93 | 5.93 | 5.56 | 5.56 |
| **4.0** | 8.33 | 8.33 | 8.05 | 8.05 | 6.69 | 6.69 | 6.18 | 5.93 | 5.93 | 5.93 | 5.93 | 5.57 | 5.57 |
| **4.5** | 8.33 | 8.33 | 8.05 | 8.05 | 6.91 | 6.91 | 6.28 | 6.18 | 6.18 | 6.18 | 6.18 | 5.97 | 5.97 |
| **5.0** | 8.34 | 8.34 | 8.13 | 8.13 | 7.62 | 7.62 | 6.84 | 6.83 | 6.83 | 6.83 | 6.83 | 6.61 | 6.61 |
| **5.5** | 8.68 | 8.68 | 8.68 | 8.68 | 8.38 | 8.38 | 7.50 | 7.49 | 7.49 | 7.49 | 7.49 | 7.25 | 7.25 |
| **6.0** | 9.38 | 9.38 | 9.44 | 9.44 | 9.12 | 9.12 | 8.17 | 8.17 | 8.17 | 8.17 | 8.15 | 7.91 | 7.91 |
| **6.5** | 10.15 | 10.15 | 10.22 | 10.22 | 9.89 | 9.89 | 8.85 | 8.84 | 8.84 | 8.84 | 8.83 | 8.56 | 8.56 |
| **7.0** | 10.94 | 10.94 | 11.01 | 11.01 | 10.67 | 10.68 | 9.51 | 9.50 | 9.49 | 9.49 | 9.35 | 9.21 | 9.21 |
| **7.5** | 11.72 | 11.72 | 11.80 | 11.80 | 11.38 | 11.38 | 10.13 | 10.13 | 10.13 | 10.11 | 9.58 | 9.87 | 9.87 |
| **8.0** | 12.49 | 12.49 | 12.57 | 12.57 | 12.16 | 12.16 | 10.86 | 10.84 | 10.84 | 10.65 | 9.69 | 10.51 | 10.51 |
| **8.5** | 13.22 | 13.25 | 13.28 | 13.31 | 12.90 | 12.90 | 11.52 | 11.43 | 11.49 | 10.88 | 9.76 | 11.12 | 11.12 |
| **9.0** | 13.67 | 13.77 | 13.70 | 13.81 | 13.50 | 13.55 | 12.16 | 11.73 | 11.94 | 10.96 | 9.82 | 11.52 | 11.52 |
| **9.5** | 13.83 | 14.00 | 13.84 | 14.01 | 13.79 | 13.94 | 12.75 | 11.83 | 12.12 | 10.97 | 9.87 | 11.64 | 11.65 |
| **10.0** | 13.85 | 14.04 | 13.85 | 14.04 | 13.84 | 14.02 | 13.18 | 11.82 | 12.13 | 10.99 | 9.91 | 11.65 | 11.65 |
| **10.5** | 13.84 | 14.03 | 13.84 | 14.03 | 13.84 | 14.02 | 13.37 | 11.82 | 12.13 | 11.02 | 9.95 | 11.67 | 11.66 |
| **11.0** | 13.83 | 14.01 | 13.83 | 14.01 | 13.84 | 14.02 | 13.41 | 11.83 | 12.13 | 11.08 | 9.97 | 11.67 | 11.67 |
| **11.5** | 13.82 | 14.01 | 13.84 | 14.01 | 13.84 | 14.03 | 13.42 | 11.83 | 12.14 | 11.13 | 9.98 | 11.67 | 11.67 |
| **12.0** | 13.85 | 14.02 | 13.84 | 14.02 | 13.85 | 14.04 | 13.42 | 11.83 | 12.15 | 11.19 | 9.98 | 11.67 | 11.67 |
| **12.5** | 13.86 | 14.04 | 13.85 | 14.03 | 13.85 | 14.04 | 13.42 | 11.83 | 12.15 | 11.25 | 9.98 | 11.67 | 11.67 |
| **13.0** | 13.86 | 14.04 | 13.85 | 14.04 | 13.85 | 14.04 | 13.42 | 11.83 | 12.15 | 11.30 | 9.97 | 11.67 | 11.67 |
| **13.5** | 13.86 | 14.04 | 13.85 | 14.04 | 13.85 | 14.04 | 13.42 | 11.83 | 12.14 | 11.34 | 9.97 | 11.67 | 11.67 |
| **14.0** | 13.86 | 14.05 | 13.85 | 14.04 | 13.85 | 14.04 | 13.42 | 11.83 | 12.14 | 11.36 | 9.97 | 11.67 | 11.67 |
| **14.5** | 13.85 | 14.05 | 13.85 | 14.04 | 13.85 | 14.04 | 13.42 | 11.83 | 12.14 | 11.38 | 9.96 | 11.67 | 11.67 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **15.0** | 13.85 | 14.04 | 13.85 | 14.04 | 13.85 | 14.04 | 13.42 | 11.83 | 12.14 | 11.40 | 9.96 | 11.67 | 11.67 |
| **15.5** | 13.85 | 14.04 | 13.85 | 14.04 | 13.85 | 14.04 | 13.42 | 11.83 | 12.14 | 11.44 | 9.96 | 11.67 | 11.67 |
| **16.0** | 13.85 | 14.04 | 13.85 | 14.04 | 13.85 | 14.04 | 13.42 | 11.83 | 12.14 | 11.49 | 9.96 | 11.67 | 11.67 |
| **16.5** | 13.85 | 14.04 | 13.85 | 14.04 | 13.85 | 14.04 | 13.42 | 11.83 | 12.14 | 11.54 | 9.96 | 11.67 | 11.67 |
| **17.0** | 13.85 | 14.04 | 13.85 | 14.04 | 13.85 | 14.04 | 13.42 | 11.83 | 12.14 | 11.57 | 9.96 | 11.67 | 11.67 |
| **17.5** | 13.86 | 14.05 | 13.85 | 14.04 | 13.85 | 14.04 | 13.42 | 11.83 | 12.14 | 11.60 | 9.96 | 11.67 | 11.67 |
| **18.0** | 13.85 | 14.05 | 13.85 | 14.04 | 13.85 | 14.04 | 13.42 | 11.83 | 12.14 | 11.60 | 9.96 | 11.67 | 11.67 |
| **18.5** | 13.85 | 14.04 | 13.85 | 14.04 | 13.85 | 14.04 | 13.42 | 11.83 | 12.14 | 11.61 | 9.96 | 11.67 | 11.67 |
| **19.0** | 13.86 | 14.05 | 13.86 | 14.05 | 13.86 | 14.05 | 13.42 | 11.83 | 12.15 | 11.61 | 9.97 | 11.67 | 11.67 |
| **19.5** | 13.86 | 14.05 | 13.86 | 14.05 | 13.86 | 14.05 | 13.42 | 11.83 | 12.15 | 11.65 | 9.96 | 11.67 | 11.67 |
| **20.0** | 13.86 | 14.05 | 13.86 | 14.05 | 13.86 | 14.05 | 13.42 | 11.83 | 12.15 | 11.68 | 9.96 | 11.67 | 11.67 |
| **20.5** | 13.86 | 14.05 | 13.86 | 14.05 | 13.85 | 14.04 | 13.42 | 11.83 | 12.15 | 11.71 | 9.96 | 11.60 | 11.60 |
| **21.0** | 13.86 | 14.05 | 13.86 | 14.04 | 13.85 | 14.04 | 13.42 | 11.83 | 12.15 | 11.74 | 9.96 | 11.29 | 11.29 |
| **21.5** | 13.85 | 14.04 | 13.85 | 14.04 | 13.85 | 14.04 | 13.42 | 11.83 | 12.14 | 11.76 | 9.97 | 10.83 | 10.83 |
| **22.0** | 13.85 | 14.04 | 13.85 | 14.04 | 13.85 | 14.04 | 13.33 | 11.83 | 12.14 | 11.79 | 9.97 | 10.27 | 10.27 |
| **22.5** | 13.85 | 14.04 | 13.85 | 14.03 | 13.85 | 14.04 | 12.83 | 11.83 | 12.14 | 11.81 | 9.97 | 9.71 | 9.71 |
| **23.0** | 13.80 | 13.94 | 13.78 | 13.93 | 13.80 | 13.94 | 12.04 | 11.83 | 12.15 | 11.82 | 9.97 | 9.20 | 9.20 |
| **23.5** | 13.61 | 13.70 | 13.57 | 13.66 | 13.60 | 13.70 | 11.17 | 11.83 | 12.13 | 11.83 | 9.97 | 8.66 | 8.67 |
| **24.0** | 13.25 | 13.29 | 13.20 | 13.22 | 13.24 | 13.27 | 10.42 | 11.76 | 12.00 | 11.76 | 9.97 | 8.17 | 8.16 |
| **24.5** | 12.78 | 12.78 | 12.68 | 12.68 | 12.74 | 12.74 | 9.67 | 11.43 | 11.59 | 11.45 | 9.97 | 7.76 | 7.76 |
| **25.0** | 12.26 | 12.27 | 12.14 | 12.14 | 12.17 | 12.14 | 8.91 | 10.89 | 10.93 | 10.89 | 9.97 | 7.45 | 7.45 |
| **25.5** | 11.74 | 11.75 | 11.60 | 11.60 | 11.48 | 11.47 | 8.20 | 10.30 | 10.34 | 10.30 | 9.95 | 7.29 | 7.29 |
| **26.0** | 11.23 | 11.22 | 11.04 | 11.03 | 10.90 | 10.89 | 7.60 | 9.88 | 9.88 | 9.88 | 9.90 | 7.19 | 7.19 |
| **26.5** | 10.72 | 10.72 | 10.48 | 10.49 | 10.29 | 10.30 | 7.23 | 9.67 | 9.67 | 9.68 | 9.78 | 7.15 | 7.15 |
| **27.0** | 10.17 | 10.17 | 9.89 | 9.89 | 9.89 | 9.87 | 7.08 | 9.53 | 9.54 | 9.53 | 9.55 | 7.14 | 7.14 |
| **27.5** | 9.61 | 9.61 | 9.32 | 9.32 | 9.43 | 9.44 | 7.06 | 9.25 | 9.25 | 9.26 | 9.12 | 7.14 | 7.14 |
| **28.0** | 9.12 | 9.13 | 8.87 | 8.87 | 9.02 | 9.01 | - | 8.81 | 8.81 | 8.81 | 8.63 | - | - |
| **28.5** | 8.82 | 8.82 | 8.66 | 8.66 | 8.72 | 8.72 | - | 8.32 | 8.31 | 8.32 | 8.11 | - | - |
| **29.0** | 8.65 | 8.65 | 8.61 | 8.61 | 8.62 | 8.62 | - | 7.83 | 7.83 | 7.83 | 7.78 | - | - |
| **29.5** | 8.60 | 8.60 | 8.59 | 8.59 | 8.59 | 8.60 | - | 7.46 | 7.46 | 7.46 | 7.45 | - | - |
| **30.0** | 8.59 | 8.59 | 8.59 | 8.59 | 8.59 | 8.59 | - | 7.27 | 7.27 | 7.27 | 7.27 | - | - |

# 5. Average generator speed vs. wind speed (HWO)

| | V105 | V105 | V112 | V112 | V117 | V117 | V126 | V126 | V126 | V126 | V126 | V136 | V136 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 3.45MW | 3.6MW | 3.45MW | 3.6MW | 3.45MW | 3.6MW | 3.45MW | 3.45MW | 3.6MW | 3.45MW | 3.45MW | 3.45MW | 3.6MW |
| | | | | | | | Low Torque | High Torque | High Torque | High Torque | High Torque | | |
| | Mode 0 | PO1 | Mode 0 | PO1 | Mode 0 | PO1 | Mode 0 | Mode 0 | PO1 | SO1 | SO2 | Mode 0 | PO1 |
| Wind Speed [m/s] | Speed [RPM] | Speed [RPM] | Speed [RPM] | Speed [RPM] | Speed [RPM] | Speed [RPM] | Speed [RPM] | Speed [RPM] | Speed [RPM] | Speed [RPM] | Speed [RPM] | Speed [RPM] | Speed [RPM] |
| **3.0** | 814 | 814 | 840 | 840 | 700 | 700 | 700 | 747 | 747 | 747 | 747 | 700 | 700 |
| **3.5** | 872 | 872 | 843 | 843 | 700 | 700 | 700 | 747 | 747 | 747 | 747 | 700 | 700 |
| **4.0** | 872 | 872 | 843 | 843 | 700 | 700 | 700 | 747 | 747 | 747 | 747 | 702 | 702 |
| **4.5** | 872 | 872 | 843 | 843 | 724 | 724 | 712 | 779 | 779 | 779 | 779 | 752 | 752 |
| **5.0** | 873 | 873 | 851 | 851 | 798 | 798 | 775 | 860 | 860 | 860 | 860 | 833 | 833 |
| **5.5** | 909 | 909 | 909 | 909 | 877 | 877 | 850 | 944 | 944 | 944 | 944 | 914 | 914 |
| **6.0** | 982 | 982 | 988 | 988 | 955 | 955 | 926 | 1029 | 1029 | 1029 | 1027 | 997 | 997 |
| **6.5** | 1063 | 1063 | 1070 | 1070 | 1036 | 1036 | 1003 | 1114 | 1114 | 1114 | 1112 | 1079 | 1079 |
| **7.0** | 1145 | 1145 | 1153 | 1153 | 1117 | 1118 | 1078 | 1197 | 1196 | 1196 | 1178 | 1161 | 1161 |
| **7.5** | 1227 | 1227 | 1235 | 1235 | 1192 | 1192 | 1148 | 1276 | 1276 | 1274 | 1207 | 1243 | 1243 |
| **8.0** | 1308 | 1308 | 1316 | 1316 | 1273 | 1273 | 1230 | 1366 | 1366 | 1342 | 1221 | 1324 | 1324 |
| **8.5** | 1384 | 1387 | 1390 | 1394 | 1351 | 1351 | 1305 | 1440 | 1448 | 1370 | 1230 | 1401 | 1401 |
| **9.0** | 1431 | 1442 | 1434 | 1446 | 1413 | 1419 | 1378 | 1478 | 1504 | 1380 | 1237 | 1452 | 1451 |
| **9.5** | 1448 | 1466 | 1449 | 1467 | 1444 | 1459 | 1445 | 1490 | 1527 | 1382 | 1243 | 1467 | 1468 |
| **10.0** | 1450 | 1470 | 1450 | 1470 | 1449 | 1468 | 1493 | 1489 | 1529 | 1384 | 1248 | 1468 | 1468 |
| **10.5** | 1449 | 1469 | 1449 | 1469 | 1449 | 1468 | 1515 | 1489 | 1528 | 1388 | 1253 | 1470 | 1469 |
| **11.0** | 1448 | 1467 | 1448 | 1467 | 1449 | 1468 | 1519 | 1490 | 1529 | 1396 | 1256 | 1470 | 1470 |
| **11.5** | 1447 | 1467 | 1449 | 1467 | 1449 | 1469 | 1520 | 1490 | 1530 | 1402 | 1257 | 1471 | 1471 |
| **12.0** | 1450 | 1468 | 1449 | 1468 | 1450 | 1470 | 1520 | 1491 | 1531 | 1409 | 1257 | 1471 | 1471 |
| **12.5** | 1451 | 1470 | 1450 | 1469 | 1450 | 1470 | 1520 | 1491 | 1531 | 1417 | 1257 | 1470 | 1471 |
| **13.0** | 1451 | 1470 | 1450 | 1470 | 1450 | 1470 | 1520 | 1491 | 1531 | 1424 | 1256 | 1470 | 1470 |
| **13.5** | 1451 | 1470 | 1450 | 1470 | 1450 | 1470 | 1520 | 1490 | 1530 | 1428 | 1256 | 1470 | 1470 |
| **14.0** | 1451 | 1471 | 1450 | 1470 | 1450 | 1470 | 1520 | 1490 | 1530 | 1431 | 1256 | 1470 | 1470 |
| **14.5** | 1450 | 1471 | 1450 | 1470 | 1450 | 1470 | 1520 | 1490 | 1530 | 1433 | 1255 | 1470 | 1470 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **15.0** | 1450 | 1470 | 1450 | 1470 | 1450 | 1470 | 1520 | 1490 | 1530 | 1436 | 1255 | 1470 | 1470 |
| **15.5** | 1450 | 1470 | 1450 | 1470 | 1450 | 1470 | 1520 | 1490 | 1530 | 1441 | 1255 | 1470 | 1470 |
| **16.0** | 1450 | 1470 | 1450 | 1470 | 1450 | 1470 | 1520 | 1490 | 1530 | 1447 | 1255 | 1470 | 1470 |
| **16.5** | 1450 | 1470 | 1450 | 1470 | 1450 | 1470 | 1520 | 1490 | 1530 | 1454 | 1255 | 1470 | 1470 |
| **17.0** | 1450 | 1470 | 1450 | 1470 | 1450 | 1470 | 1520 | 1490 | 1530 | 1458 | 1255 | 1470 | 1470 |
| **17.5** | 1451 | 1471 | 1450 | 1470 | 1450 | 1470 | 1520 | 1490 | 1530 | 1461 | 1255 | 1470 | 1470 |
| **18.0** | 1450 | 1471 | 1450 | 1470 | 1450 | 1470 | 1520 | 1490 | 1530 | 1461 | 1255 | 1470 | 1470 |
| **18.5** | 1450 | 1470 | 1450 | 1470 | 1450 | 1470 | 1520 | 1490 | 1530 | 1462 | 1255 | 1470 | 1470 |
| **19.0** | 1451 | 1471 | 1451 | 1471 | 1451 | 1471 | 1521 | 1491 | 1531 | 1463 | 1256 | 1470 | 1470 |
| **19.5** | 1451 | 1471 | 1451 | 1471 | 1451 | 1471 | 1521 | 1491 | 1531 | 1467 | 1255 | 1470 | 1470 |
| **20.0** | 1451 | 1471 | 1451 | 1471 | 1451 | 1471 | 1521 | 1491 | 1531 | 1471 | 1255 | 1470 | 1470 |
| **20.5** | 1451 | 1471 | 1451 | 1471 | 1450 | 1470 | 1521 | 1491 | 1531 | 1475 | 1255 | 1461 | 1461 |
| **21.0** | 1451 | 1471 | 1451 | 1470 | 1450 | 1470 | 1521 | 1491 | 1531 | 1479 | 1255 | 1423 | 1423 |
| **21.5** | 1450 | 1470 | 1450 | 1470 | 1450 | 1470 | 1520 | 1490 | 1530 | 1482 | 1256 | 1364 | 1364 |
| **22.0** | 1450 | 1470 | 1450 | 1470 | 1450 | 1470 | 1510 | 1490 | 1530 | 1485 | 1256 | 1294 | 1294 |
| **22.5** | 1450 | 1470 | 1450 | 1469 | 1450 | 1470 | 1454 | 1490 | 1530 | 1488 | 1256 | 1224 | 1223 |
| **23.0** | 1445 | 1460 | 1443 | 1458 | 1445 | 1460 | 1364 | 1491 | 1531 | 1489 | 1256 | 1159 | 1159 |
| **23.5** | 1425 | 1434 | 1421 | 1430 | 1424 | 1434 | 1266 | 1491 | 1529 | 1490 | 1256 | 1091 | 1092 |
| **24.0** | 1387 | 1391 | 1382 | 1384 | 1386 | 1389 | 1181 | 1482 | 1512 | 1481 | 1256 | 1029 | 1028 |
| **24.5** | 1338 | 1338 | 1328 | 1328 | 1334 | 1334 | 1096 | 1440 | 1460 | 1442 | 1256 | 978 | 978 |
| **25.0** | 1284 | 1285 | 1271 | 1271 | 1274 | 1271 | 1010 | 1372 | 1377 | 1372 | 1256 | 939 | 939 |
| **25.5** | 1229 | 1230 | 1214 | 1214 | 1202 | 1201 | 929 | 1298 | 1303 | 1298 | 1253 | 918 | 918 |
| **26.0** | 1176 | 1175 | 1156 | 1155 | 1141 | 1140 | 861 | 1245 | 1245 | 1245 | 1247 | 906 | 906 |
| **26.5** | 1122 | 1122 | 1097 | 1098 | 1077 | 1078 | 819 | 1219 | 1219 | 1219 | 1232 | 901 | 901 |
| **27.0** | 1065 | 1065 | 1035 | 1035 | 1035 | 1033 | 802 | 1201 | 1202 | 1201 | 1203 | 900 | 900 |
| **27.5** | 1006 | 1006 | 976 | 976 | 987 | 988 | 800 | 1166 | 1166 | 1166 | 1149 | 900 | 900 |
| **28.0** | 955 | 956 | 929 | 929 | 944 | 943 | - | 1110 | 1110 | 1110 | 1087 | - | - |
| **28.5** | 923 | 923 | 907 | 907 | 913 | 913 | - | 1048 | 1047 | 1048 | 1022 | - | - |
| **29.0** | 906 | 906 | 901 | 901 | 902 | 902 | - | 986 | 986 | 986 | 980 | - | - |
| **29.5** | 900 | 900 | 899 | 899 | 899 | 900 | - | 940 | 940 | 940 | 939 | - | - |
| **30.0** | 899 | 899 | 899 | 899 | 899 | 899 | - | 916 | 916 | 916 | 916 | - | - |

# 6. 10 min Average/1 sec max rotor speed vs. wind speed in Idle

| | V105 | V105 | V112 | V112 | V117 | V117 | V126 | V126 | V136 | V136 |
|---|---|---|---|---|---|---|---|---|---|---|
| Wind Speed [m/s] | Average Speed [RPM] | Max Speed [RPM] | Average Speed [RPM] | Max Speed [RPM] | Average Speed [RPM] | Max Speed [RPM] | Average Speed [RPM] | Max Speed [RPM | Average Speed [RPM] | Max Speed [RPM |
| **0.0** | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| **1.0** | 0,05 | 0,11 | 0,05 | 0,11 | 0,06 | 0,11 | 0,06 | 0,12 | 0,08 | 0,12 |
| **2.0** | 0,11 | 0,21 | 0,11 | 0,21 | 0,12 | 0,21 | 0,12 | 0,23 | 0,15 | 0,24 |
| **3.0** | 0,16 | 0,32 | 0,16 | 0,32 | 0,18 | 0,32 | 0,18 | 0,35 | 0,23 | 0,36 |
| **4.0** | 0,22 | 0,42 | 0,22 | 0,42 | 0,23 | 0,42 | 0,24 | 0,46 | 0,30 | 0,48 |
| **5.0** | 0,27 | 0,53 | 0,27 | 0,53 | 0,29 | 0,53 | 0,30 | 0,58 | 0,38 | 0,60 |
| **6.0** | 0,32 | 0,64 | 0,32 | 0,64 | 0,35 | 0,64 | 0,36 | 0,70 | 0,46 | 0,72 |
| **7.0** | 0,38 | 0,74 | 0,38 | 0,74 | 0,41 | 0,74 | 0,42 | 0,81 | 0,53 | 0,84 |
| **8.0** | 0,43 | 0,85 | 0,43 | 0,85 | 0,47 | 0,85 | 0,48 | 0,93 | 0,61 | 0,96 |
| **9.0** | 0,49 | 0,95 | 0,49 | 0,95 | 0,53 | 0,95 | 0,54 | 1,04 | 0,68 | 1,08 |
| **10.0** | 0,54 | 1,06 | 0,54 | 1,06 | 0,58 | 1,06 | 0,60 | 1,16 | 0,76 | 1,20 |
| **11.0** | 0,59 | 1,17 | 0,59 | 1,17 | 0,64 | 1,17 | 0,66 | 1,28 | 0,84 | 1,32 |
| **12.0** | 0,65 | 1,27 | 0,65 | 1,27 | 0,70 | 1,27 | 0,72 | 1,39 | 0,91 | 1,44 |
| **13.0** | 0,70 | 1,38 | 0,70 | 1,38 | 0,76 | 1,38 | 0,78 | 1,51 | 0,99 | 1,56 |
| **14.0** | 0,76 | 1,48 | 0,76 | 1,48 | 0,82 | 1,48 | 0,84 | 1,62 | 1,06 | 1,68 |
| **15.0** | 0,81 | 1,59 | 0,81 | 1,59 | 0,88 | 1,59 | 0,90 | 1,74 | 1,14 | 1,80 |
| **16.0** | 0,86 | 1,70 | 0,86 | 1,70 | 0,93 | 1,70 | 0,96 | 1,86 | 1,22 | 1,92 |
| **17.0** | 0,92 | 1,80 | 0,92 | 1,80 | 0,99 | 1,80 | 1,02 | 1,97 | 1,29 | 2,04 |
| **18.0** | 0,97 | 1,91 | 0,97 | 1,91 | 1,05 | 1,91 | 1,08 | 2,09 | 1,37 | 2,16 |
| **19.0** | 1,03 | 2,01 | 1,03 | 2,01 | 1,11 | 2,01 | 1,14 | 2,20 | 1,44 | 2,28 |
| **20.0** | 1,08 | 2,12 | 1,08 | 2,12 | 1,17 | 2,12 | 1,20 | 2,32 | 1,52 | 2,40 |
| **21.0** | 1,13 | 2,23 | 1,13 | 2,23 | 1,23 | 2,23 | 1,26 | 2,44 | 1,60 | 2,52 |
| **22.0** | 1,19 | 2,33 | 1,19 | 2,33 | 1,28 | 2,33 | 1,32 | 2,55 | 1,67 | 2,64 |
| **23.0** | 1,24 | 2,44 | 1,24 | 2,44 | 1,34 | 2,44 | 1,38 | 2,67 | 1,75 | 2,76 |
| **24.0** | 1,30 | 2,54 | 1,30 | 2,54 | 1,40 | 2,54 | 1,44 | 2,78 | 1,82 | 2,88 |
| **25.0** | 1,35 | 2,65 | 1,35 | 2,65 | 1,46 | 2,65 | 1,50 | 2,90 | 1,90 | 3,00 |

## 7. Transition time from Production to Idle.

Based on numerous simulations, the duration from a shutdown (pause) command is sent to the turbine and until the turbine reaches steady state Idle rotor speed below 2 RPM, has been determined to be between 20 and 40 seconds. Actual timing is dependent on windspeed, turbulence etc., but not significantly dependent on the rotor size

## 8. Additional remarks

The listed RPM curves are not valid for noise modes. load modes or other power modes. Only noise modes for V126-3.45MW High Torque SO1 and SO2 is included.

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# General Specification

## V126-3.3 MW 50/60 Hz

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**See general reservations, notes and disclaimers (including, section 11, p. 36) to this general specification.**

# 1 General Description

The Vestas V126-3.3 MW wind turbine is a pitch regulated upwind turbine with active yaw and a three-blade rotor. The Vestas V126-3.3 MW turbine has a rotor diameter of 126 m and a rated output power of 3.3 MW. The turbine 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 maintaining 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.

# 2 Mechanical Design

## 2.1 Rotor

The V126-3.3 MW is equipped with a 126-meter 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** | |
|---|---|
| **Diameter** | 126 m |
| **Swept Area** | 12469 $m^2$ |
| **Speed, Dynamic Operation Range** | 5.3-16.5 |
| **Rotational Direction** | Clockwise (front view) |
| **Orientation** | Upwind |
| **Tilt** | 6° |
| **Blade Coning** | 4° |
| **Number of Blades** | 3 |
| **Aerodynamic Brakes** | Full feathering |

*Table 2-1: Rotor data*

## 2.2 Blades

The blades are made of carbon and fibreglass and consist of two infused structural airfoil shells.

| **Blades** | |
|---|---|
| **Type Description** | Infused structural airfoil shell |
| **Blade Length** | 61.66 m |
| **Material** | Fibreglass reinforced epoxy, carbon fibres and Solid Metal Tip (SMT) |
| **Blade Connection** | Steel roots inserted |
| **Airfoils** | High-lift profile |

| Blades | |
|---|---|
| **Maximum Chord** | 4.0 m |

*Table 2-2: Blades data*

## 2.3 Blade Bearing

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

| Blade Bearing | |
|---|---|
| **Lubrication** | Grease |

*Table 2-3: Blade bearing data*

## 2.4 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 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** | -9.5° to 90° |

*Table 2-4: Pitch system data*

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

*Table 2-5: Hydraulic system data*

## 2.5 Hub

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

| Hub | |
|---|---|
| **Type** | Cast ball shell hub |
| **Material** | Cast iron |

*Table 2-6: Hub data*

## 2.6 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 2-7: Main shaft data*

## 2.7 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 2-8: Main bearing housing data*

## 2.8 Main Bearing

The main bearing carries all thrust loads.

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

*Table 2-9: Main bearing data*

## 2.9 Gearbox

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

The disc brake is installed 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 |

| Gearbox | |
|---|---|
| **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 2-10: Gearbox data*

## 2.10 Generator Bearings

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

## 2.11 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.

## 2.12 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.<br>Plain bearings PETP |
| **Yawing Speed (50 Hz)** | 0.46°/sec. |
| **Yawing Speed (60 Hz)** | 0.60°/sec |

*Table 2-11: 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 2-12: Yaw gear data*

## 2.13 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 2-13: Crane data*

## 2.14 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.

The hub heights listed 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 the tower top flange to the centre of the hub of 2.2 m.

| Towers | |
|---|---|
| **Type** | Cylindrical/conical tubular |
| **Hub Heights** | 117 m/128 m/137 m |

*Table 2-14: Tower structure data*

## 2.15 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 mounted on the nacelle bedplate.

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

*Table 2-15: Nacelle bedplate and cover data*

## 2.16 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.

### 2.16.1 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.

### 2.16.2 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.

### 2.16.3 Transformer Cooling

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

### 2.16.4 Nacelle Cooling

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

### 2.16.5 Optional Air Intake Hatches

The air intakes in the nacelle can optionally 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.

# 3 Electrical Design

## 3.1 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 installed on top of the generator.

| **Generator** | |
|---|---|
| **Type** | Asynchronous with cage rotor |
| **Rated Power [$P_N$]** | 3500 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 3-1: Generator data*

## 3.2 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 four 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** | 3286 A |
| **Enclosure** | IP54 |

*Table 3-2: Converter data*

## 3.3 HV Transformer

The HV step-up 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.

### 3.3.1 IEC 50Hz/60Hz version

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.

| Transformer | |
|---|---|
| **Type description** | Dry-type cast resin transformer. |
| **Basic layout** | 3 phase, 2 winding transformer. |
| **Applied standards** | IEC 60076-11, IEC 60076-16, Cenelec HD 637:S1. |
| **Cooling method** | AF |
| **Rated power** | 3750 kVA |
| **Nominal voltage, turbine side** | |
| **$U_m$ 1.1kV** | 0.650 kV |
| **Nominal 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** | 33.1-35.0 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** [3] | 16kVAr |
| **Full load reactive power** [3] | 330kVAr |
| **Positive sequence short-circuit impedance @ rated power, 120°C** [4] | 9.0 % |
| **Positive sequence short-circuit resistance@ rated power, 120°C**[3] | 0.7 % |
| **Zero sequence short-circuit impedance@ rated power, 120°C**[3] | 9.0 % |
| **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 @ 1000m** | ≤ 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** | ≤8500 kg |
| **Temperature monitoring** | PT100 sensors in LV windings and core |
| **Overvoltage protection** | Surge arresters on HV terminals |
| **Temporary earthing** | 3 x Ø20mm earthing ball points |

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

**NOTE**

[1] @1000m. According to IEC 60076-11, AC test voltage is altitude dependent.
[2] Based on an average of measured values during qualification tests across voltages and manufacturers.
[3] Based on an average of calculated values across voltages and manufacturers.
[4] Subjected to standard IEC tolerances.
[5] Max hub height altitude will depend on site location.

### 3.3.2 IEEE 60 Hz version

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.

| **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, Cenelec HD 637:S1. |
| **Cooling method** | AFA |
| **Rated power** | 3750 kVA |
| **Nominal voltage, turbine side** | |
| **$N_{LL}$ 1.2 kV** | 0.650 kV |
| **Nominal 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 [3]** | 16 kVAr |
| **Full load reactive power [3]** | 330 kVAr |
| **Positive sequence short-circuit impedance @ rated power, 120°C [4]** | 9.0 % |
| **Positive sequence short-circuit resistance @ rated power, 120°C [3]** | 0.7 % |
| **Zero sequence short-circuit impedance @ rated power, 120°C [3]** | 9.0 % |
| **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 @ 1000m** | ≤ 90 K |
| **Max altitude** [5] | 2000 m |
| **Insulation class** | 150°C |
| **Environmental class** | E2 |
| **Climatic class** | C2 |
| **Fire behaviour class** | F1 |
| **Corrosion class** | C4 |
| **Weight** | ≤ 8500 kg |
| **Temperature monitoring** | PT100 sensors in LV windings and core |
| **Overvoltage protection** | Surge arresters on HV terminals |
| **Temporary earthing** | 3 x Ø20mm earthing ball points |

*Table 3-4: Transformer data for IEEE 60 Hz version*

**NOTE**

[1] @1000m. According to IEEE C57.12, AC test voltage is altitude dependent.
[2] Based on an average of measured values during qualification tests across voltages and manufacturers.
[3] Based on an average of calculated values across voltages and manufacturers.
[4] Subjected to standard IEEE C57.12 tolerances.
[5] Max hub height altitude will depend on site location.

## 3.4 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 10-22 kV rated voltage<br>42 kV for 22.1-35 kV rated voltage |

*Table 3-4: HV cables data*

## 3.5 HV Switchgear

The HV switchgear is located in the bottom of the tower.

| HV Switchgear | | | |
|---|---|---|---|
| **Type** | Gas insulated SF6 | | |
| **Nominal Frequency** | 50/60 Hz | | |
| **Nominal Rated Voltage** | 10–22 kV | 22.1–33 kV | 33.1–35 kV |
| **Maximum Voltage** | 24 kV | 36 kV | 40.5 kV |
| **Maximum Short Circuit Current (1 second)** | 20 kA | 25 kA | 25 kA |

*Table 3-5: HV switchgear data*

## 3.6 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)/<br>2 x 55 V (16 A) |
| **Three Phase (Nacelle and Tower Base)** | 3 x 400 V (16 A) |

*Table 3-6: AUX system data*

## 3.7 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.

## 3.8 Vestas Multi Processor (VMP) Controller

The turbine is controlled and monitored by the VMP6000 control system.

VMP6000 is a multiprocessor control system comprised of four main processors (ground, nacelle, hub and converter) interconnected by an optically based 2.5 Mbit ArcNet network.

In addition to the four main processors, the VMP6000 consists of a number of distributed I/O modules interconnected by a 500 kbit CAN network.

I/O modules are connected to CAN interface modules by a serial digital bus, CTBus.

The VMP6000 controller 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.

## 3.9 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 3-8: 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.

# 4 Turbine Protection Systems

## 4.1 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.

## 4.2 Short Circuit Protections

| **Breakers** | **Breaker for Aux. Power.**<br>**T4L 250A TMD 4P**<br>**690 V** | **Breaker for Converter Modules**<br>**T7M1200L PR332/P LSIG 1000 A 3P**<br>**690 V** |
|---|---|---|
| **Breaking Capacity, Icu, Ics** | 70 kA@690 V | 50 kA @690 V |
| **Making Capacity, Icm** | 154 kA@690 V | 105 kA @690 V |

*Table 4-1: Short circuit protection data*

## 4.3 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** | 16.5 (rotor rpm)/1871 (generator rpm) |

*Table 4-3: Overspeed protection data*

## 4.4 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.

## 4.5 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.

## 4.6 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 4-4: Lightning protection design parameters*

**NOTE** The Lightning Protection System is designed according to IEC standards (see 7 Approvals and Design Codes, p. 24).

## 4.7 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.

## 4.8 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.

## 4.9 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 4-5: Corrosion protection data for nacelle, hub and tower*

# 5 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.

## 5.1 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.

## 5.2 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.

## 5.3 Rooms/Working Areas

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

## 5.4 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.

## 5.5 Service Lift

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

## 5.6 Climbing Facilities

A ladder with a fall arrest system (rigid rail) is mounted 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.

## 5.7 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.

## 5.8 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.

## 5.9 Emergency Stop

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

## 5.10 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.

## 5.11 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.

## 5.12 Warning Signs

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

## 5.13 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.

# 6 Environment

## 6.1 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

# 7 Approvals and Design Codes

## 7.1 Type Approvals

The standard turbine is type certified according to the certification standards listed below:

| Certification | Wind Class | Hub Height |
|---|---|---|
| **IEC61400-22** | IEC IIIB | 117 m |
| **IEC61400-22** | IEC IIIA | 128 m |
| **IEC61400-22** | IEC IIIA | 137 m |
| **DIBt 2012** | WZ2, GKII, TKA | 137 m |

*Table 7-1: Type approvals data*

## 7.2 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<br>EN 50308 |
| **Tower** | IEC 61400-1 Edition 3<br>Eurocode 3 |
| **Blades** | DNV-OS-J102<br>IEC 1024-1<br>IEC 60721-2-4<br>IEC 61400 (Part 1, 12 and 23)<br>IEC WT 01 IEC<br>DEFU R25<br>ISO 2813<br>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<br>IEC 62305-3: 2006<br>IEC 62305-4: 2006<br>IEC 61400-24:2010 |
| **Rotating Electrical Machines** | IEC 34 |
| **Safety of Machinery, Safety-** | IEC 13849-1 |

| Design Codes | |
|---|---|
| **related Parts of Control Systems** | |
| **Safety of Machinery – Electrical Equipment of Machines** | IEC 60204-1 |

*Table 7-2: Design codes*

# 8 Colours

## 8.1 Nacelle Colour

| Colour of Vestas Nacelles | |
|---|---|
| **Standard Nacelle Colour** | RAL 7035 (light grey) |
| **Standard Logo** | Vestas |

*Table 8-1: Colour, nacelle*

## 8.2 Tower Colour

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

*Table 8-2: Colour, tower*

## 8.3 Blades Colour

| Blades 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 8-3: Colour, blades*

# 9 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.

## 9.1 Climate and Site Conditions

Values refer to hub height:

| Extreme Design Parameters | |
|---|---|
| **Wind Climate** | **IEC IIIA** |
| **Ambient Temperature Interval (Standard Temperature Turbine)** | -40° to +50°C |
| **Extreme Wind Speed (10 Minute Average)** | 37.5 m/s |
| **Survival Wind Speed (3 Second Gust)** | 52.5 m/s |

*Table 9-1: Extreme design parameters*

| Average Design Parameters | |
|---|---|
| **Wind Climate** | **IEC IIIA** |
| **Nominal Power** | 3.3 MW |
| **Wind Speed** | 7.5 m/s |
| **A-Factor** | 8.46 m/s |
| **Form Factor, c** | 2.0 |
| **Turbulence Intensity According to IEC 61400-1, Including Wind Farm Turbulence (@15 m/s – 90% quartile)** | 18% |
| **Wind Shear** | 0.20 |
| **Inflow Angle (vertical)** | 8° |

*Table 9-2: Average design parameters*

### 9.1.1 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 site assessment.

Positioning of each turbine must be verified via the Vestas Site Check programme.

### 9.1.2 Altitude

The turbine is designed for use at altitudes up to 1000 m above sea level as standard and optional up to 2000 m above sea level.

### 9.1.3 Wind Power Plant Layout

Turbine spacing is to be evaluated site-specifically. Spacing, in any case, must not be below three rotor diameters (3D).

**NOTE** As evaluation of climate and site conditions is complex, consult Vestas for every project. If conditions exceed the above parameters, Vestas must be consulted.

## 9.2 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 | |
|---|---|
| **Ambient Temperature Interval (Standard Turbine)** | -20° to +45°C |
| **Ambient Temperature Interval (Low Temperature Turbine)** | -30° to +45°C |
| **Cut-In** | 3 m/s |
| **Cut-Out (10 Minute Exponential Average)** | 22.5m/s |
| **Re-Cut In (10 Minute Exponential Average)** | 20 m/s |

*Table 9-3: Operational envelope – temperature and wind*

**NOTE** At ambient temperatures above +30°C, the turbine will maintain derated production, within the component capacity as seen in *Figure* 9-1.

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

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

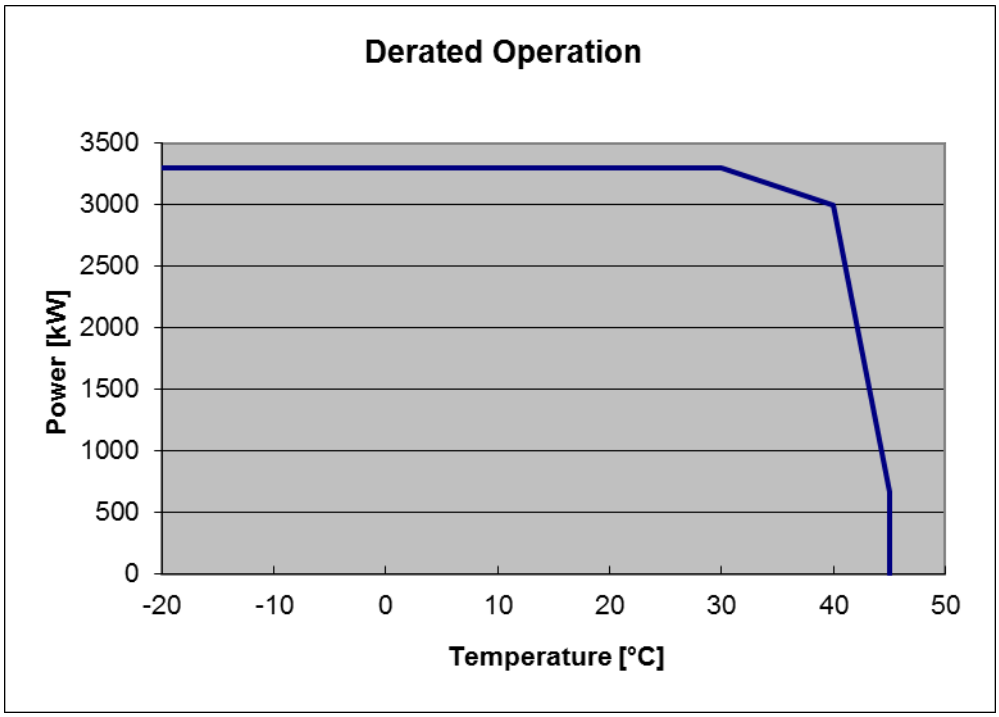



*Figure 9-1: Derated operation*

## 9.3 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)<br>1.45 p.u. (peak) | |

*Table 9-4: 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 9-5: 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.

** The turbine may be configured for continuous operation @ +/- 13 % voltage. Reactive power capability is limited for these widened settings (See section ‘Operational Envelope – Reactive Power Capability’).

## 9.4 Operational Envelope – Reactive Power Capability

The turbine has a reactive power capability as illustrated:

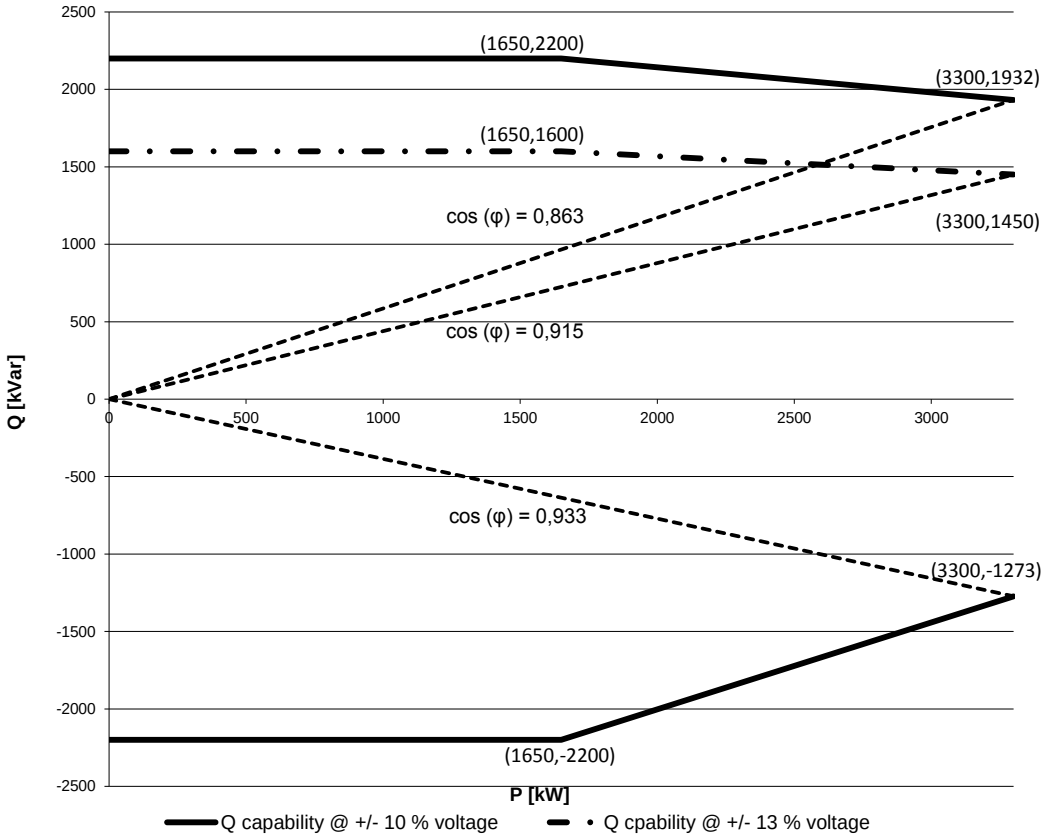



*Figure 9-2: Reactive power capability*

Reactive power capability at full load on high-voltage side of the HV transformer is approx: cosφ = 0.90/0.88 capacitive/inductive @ +/- 10 % voltage and 0.95/0.88 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.

## 9.5 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:

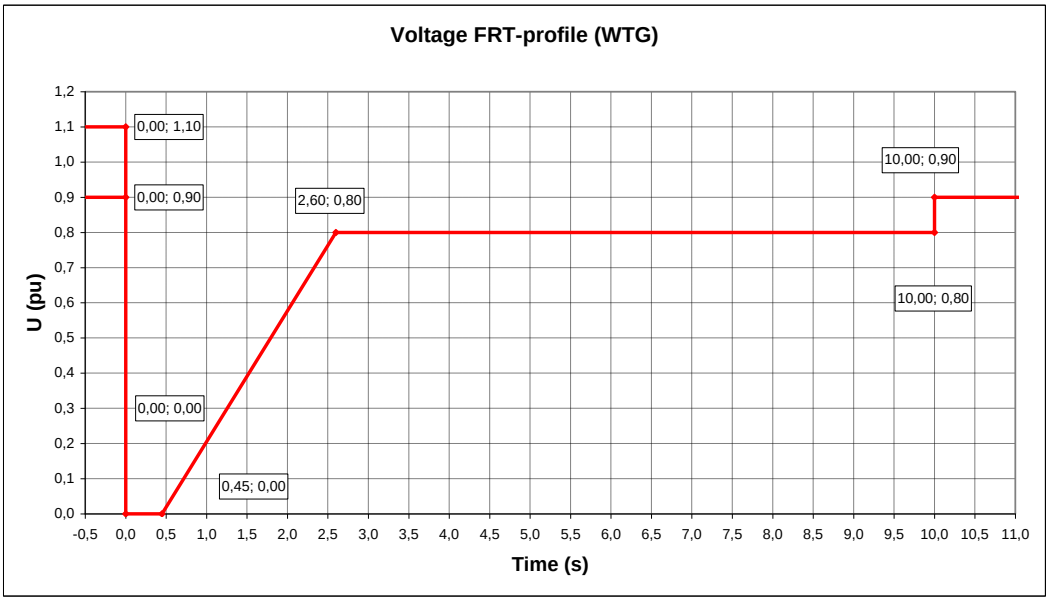



*Figure 9-3: Low voltage tolerance curve for symmetrical and asymmetrical faults, where U represents voltage as measured on the grid*

For grid disturbances outside the protection curve in Figure 9-3, the turbine will be disconnected from the grid.

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

*Table 9-6: Power recovery time*

## 9.6 Performance – Reactive Current Contribution

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

### 9.6.1 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 9-4, 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 9-4, 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.

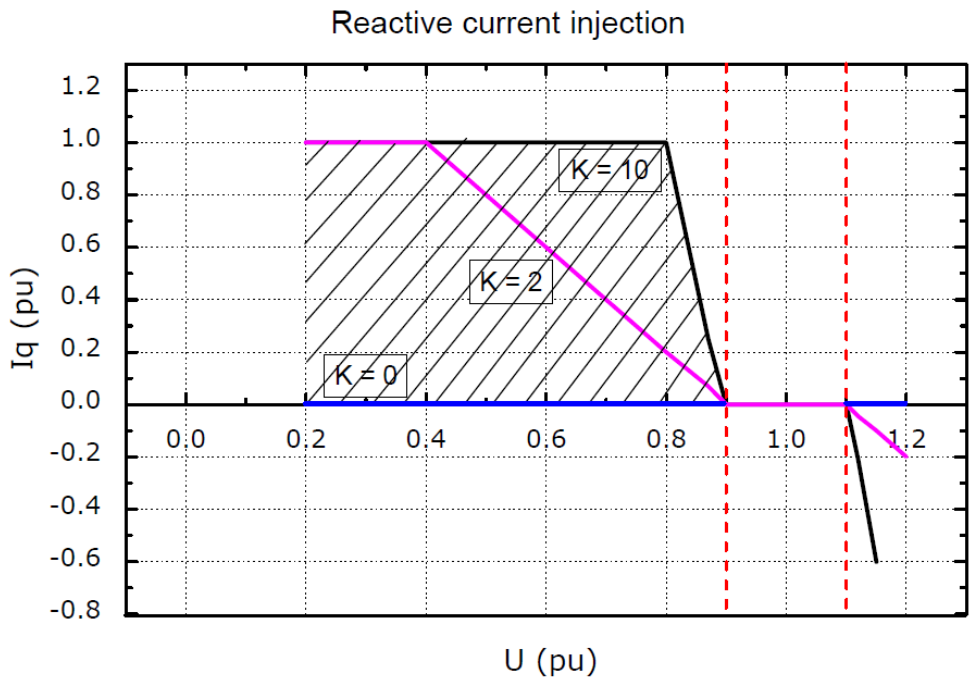



*Figure 9-4: Reactive current injection*

### 9.6.2 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.

## 9.7 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.

## 9.8 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 (330 kW/sec) |
| **Reactive Power** | 20 pu/sec (66 MVAr/sec) |

*Table 9-7: Active/reactive power ramp rates*

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.

## 9.9 Performance – Voltage Control

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

## 9.10 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.

## 9.11 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, and such like):

| 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 3.3 HV Transformer, p. 12 |

*Table 9-8: Main contributors to own consumption data*

## 9.12 Operational Envelope – Conditions for Power Curve and Ct Values (at Hub Height)

See section 12 Appendices, p. 37 for power curves and $C_t$ values.

| Conditions for Power Curve and $C_t$ Values (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 |

| Conditions for Power Curve and $C_t$ Values (at Hub Height) | |
|---|---|
| **Terrain** | IEC 61400-12-1 |
| **Inflow Angle (Vertical)** | 0 ±2° |
| **Grid Frequency** | Nominal Frequency ±0.5 Hz |

*Table 9-9: Conditions for power curve and $C_t$ values*

## 9.13 Noise Modes

The noise modes listed in Table 9-6 below are available for the V126-3.3 MW turbine.

| Available Noise Modes for V126-3.3 MW | | |
|---|---|---|
| **Mode No.** | **Maximum Noise Level** | **Standard/Option** |
| **0** | 108.5 dB | Standard |
| **0$^+$** | 106.0 dB | Option |
| **1** | 106.0 dB | Option |
| **2** | 104.5 dB | Option |
| **3** | 102.5 dB | Option |
| **4** | 101.0 dB | Option |

*Table 9-10: Available noise modes*

**NOTE**

All optional noise reduced operational modes requires special blade configuration with serrated trailing edge.

For further details on Noise Modes, see section 12 Appendices, p. 37, or contact Vestas Wind Systems A/S.

# 10 Drawings

## 10.1 Structural Design – Illustration of Outer Dimensions

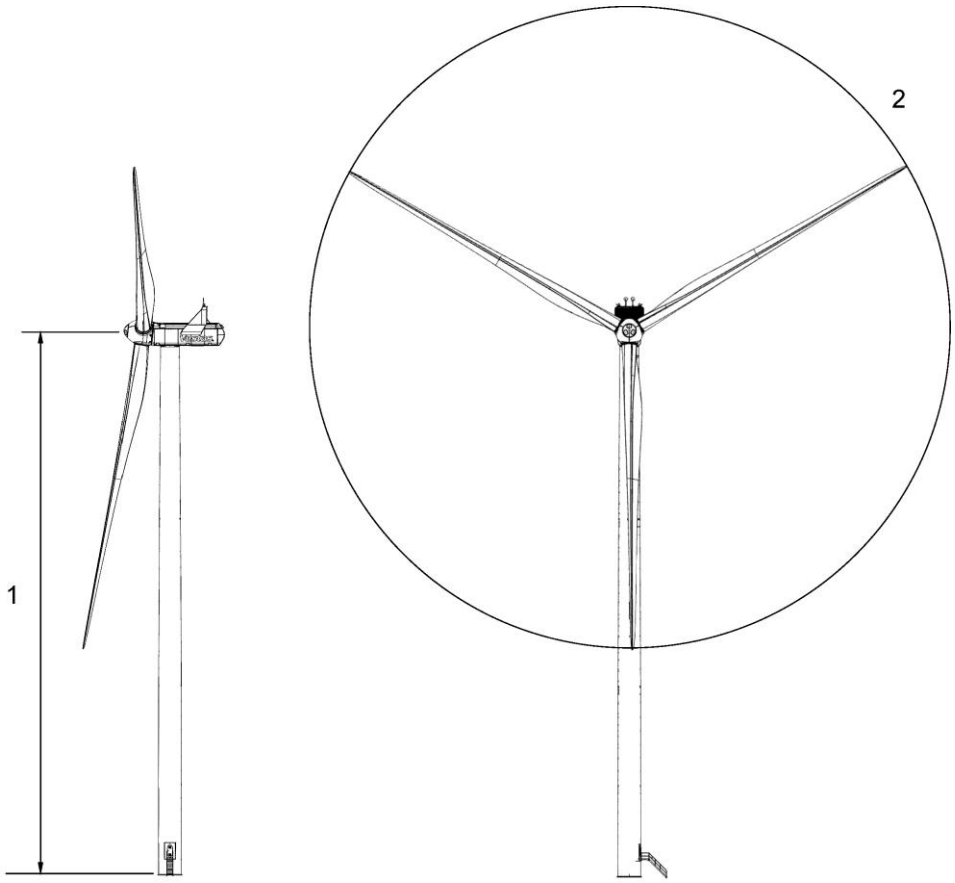



*Figure 10-1: Illustration of outer dimensions – structure*

**1** Hub height 117/128/137 m

**2** Diameter: 126 m

## 10.2 Structural Design – Side View Drawing

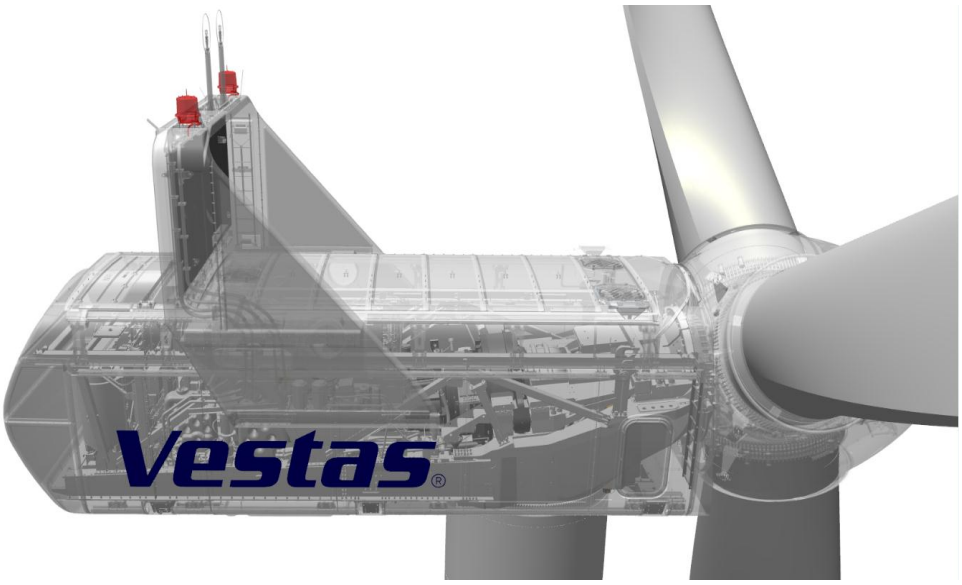



*Figure 10-2: Side-view drawing*

## 11 General Reservations, Notes and Disclaimers


- The general specifications described in this document apply to the current version of the V126-3.3 MW wind turbine. Updated versions of the V126-3.3 MW wind turbine, which may be manufactured in the future, may differ from these general specifications. In the event that Vestas supplies an updated version of the V126-3.3 MW wind turbine, Vestas will provide an updated general specification 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 Specification, 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.

# 12 Appendices

## 12.1 Mode 0/0+

### 12.1.1 Power Curves, Noise Mode 0/0+

| Air density [kg/m³] | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Wind speed [m/s]** | **1.225** | **0.95** | **0.975** | **1.0** | **1.025** | **1.05** | **1.075** | **1.1** | **1.125** | **1.15** | **1.175** | **1.2** | **1.25** | **1.275** |
| **3.0** | **30** | 13 | 14 | 16 | 17 | 19 | 20 | 22 | 23 | 25 | 27 | 28 | 32 | 33 |
| **3.5** | **97** | 63 | 66 | 69 | 72 | 75 | 78 | 81 | 84 | 87 | 91 | 94 | 100 | 103 |
| **4.0** | **179** | 128 | 133 | 138 | 142 | 147 | 152 | 156 | 161 | 166 | 170 | 175 | 184 | 189 |
| **4.5** | **278** | 205 | 212 | 219 | 225 | 232 | 239 | 245 | 252 | 259 | 265 | 272 | 285 | 292 |
| **5.0** | **397** | 297 | 306 | 315 | 324 | 333 | 342 | 351 | 360 | 369 | 378 | 388 | 406 | 415 |
| **5.5** | **539** | 407 | 420 | 432 | 444 | 455 | 467 | 479 | 491 | 503 | 515 | 527 | 551 | 563 |
| **6.0** | **711** | 541 | 557 | 572 | 588 | 603 | 619 | 634 | 650 | 665 | 680 | 696 | 726 | 742 |
| **6.5** | **913** | 699 | 718 | 738 | 758 | 777 | 797 | 816 | 836 | 855 | 874 | 894 | 933 | 952 |
| **7.0** | **1150** | 884 | 909 | 933 | 957 | 982 | 1006 | 1030 | 1054 | 1078 | 1102 | 1126 | 1174 | 1198 |
| **7.5** | **1420** | 1095 | 1125 | 1155 | 1184 | 1214 | 1244 | 1273 | 1302 | 1332 | 1361 | 1390 | 1448 | 1477 |
| **8.0** | **1723** | 1336 | 1371 | 1407 | 1442 | 1478 | 1513 | 1548 | 1584 | 1619 | 1654 | 1688 | 1757 | 1791 |
| **8.5** | **2060** | 1606 | 1648 | 1690 | 1732 | 1774 | 1815 | 1857 | 1898 | 1939 | 1979 | 2020 | 2100 | 2140 |
| **9.0** | **2434** | 1906 | 1955 | 2004 | 2053 | 2102 | 2150 | 2197 | 2245 | 2293 | 2340 | 2387 | 2480 | 2526 |
| **9.5** | **2804** | 2232 | 2287 | 2343 | 2399 | 2455 | 2507 | 2559 | 2611 | 2664 | 2710 | 2757 | 2845 | 2886 |
| **10.0** | **3090** | 2574 | 2632 | 2689 | 2747 | 2805 | 2850 | 2896 | 2941 | 2987 | 3021 | 3056 | 3117 | 3143 |
| **10.5** | **3238** | 2887 | 2933 | 2980 | 3026 | 3073 | 3102 | 3131 | 3160 | 3189 | 3205 | 3221 | 3248 | 3258 |
| **11.0** | **3290** | 3100 | 3130 | 3161 | 3191 | 3222 | 3235 | 3248 | 3261 | 3275 | 3280 | 3285 | 3293 | 3295 |
| **11.5** | **3299** | 3227 | 3240 | 3254 | 3268 | 3282 | 3285 | 3289 | 3293 | 3296 | 3297 | 3298 | 3299 | 3300 |
| **12.0** | **3300** | 3277 | 3282 | 3287 | 3291 | 3296 | 3297 | 3298 | 3299 | 3300 | 3300 | 3300 | 3300 | 3300 |
| **12.5** | **3300** | 3293 | 3295 | 3296 | 3298 | 3299 | 3299 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 |
| **13.0** | **3300** | 3298 | 3298 | 3299 | 3299 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 |
| **13.5** | **3300** | 3299 | 3299 | 3299 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 |
| **14.0** | **3300** | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 |
| **14.5** | **3300** | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 |
| **15.0** | **3300** | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 |
| **15.5** | **3300** | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 |
| **16.0** | **3300** | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 |
| **16.5** | **3300** | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 |
| **17.0** | **3300** | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 |
| **17.5** | **3300** | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 |
| **18.0** | **3300** | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 |
| **18.5** | **3300** | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 |
| **19.0** | **3300** | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 |
| **19.5** | **3300** | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 |
| **20.0** | **3300** | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 |
| **20.5** | **3300** | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 |
| **21.0** | **3300** | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 |
| **21.5** | **3300** | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 |
| **22.0** | **3300** | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 |
| **22.5** | **3300** | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 |

*Table 12-1: Power curve, noise mode 0*

### 12.1.2 $C_t$ Values, Noise Mode 0/0$^+$

| Air density kg/m$^3$ | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Wind speed [m/s]** | **1.225** | **0.950** | **0.975** | **1.0** | **1.025** | **1.05** | **1.075** | **1.1** | **1.125** | **1.15** | **1.175** | **1.2** | **1.25** | **1.275** |
| **3.0** | **0.918** | 0.927 | 0.926 | 0.925 | 0.924 | 0.924 | 0.923 | 0.922 | 0.921 | 0.920 | 0.920 | 0.919 | 0.917 | 0.917 |
| **3.5** | **0.886** | 0.893 | 0.892 | 0.892 | 0.891 | 0.890 | 0.890 | 0.889 | 0.889 | 0.888 | 0.887 | 0.887 | 0.885 | 0.885 |
| **4.0** | **0.844** | 0.850 | 0.850 | 0.849 | 0.849 | 0.848 | 0.847 | 0.847 | 0.846 | 0.846 | 0.845 | 0.845 | 0.843 | 0.843 |
| **4.5** | **0.814** | 0.820 | 0.819 | 0.819 | 0.818 | 0.817 | 0.817 | 0.816 | 0.816 | 0.815 | 0.815 | 0.814 | 0.814 | 0.813 |
| **5.0** | **0.801** | 0.807 | 0.807 | 0.806 | 0.806 | 0.805 | 0.805 | 0.804 | 0.804 | 0.803 | 0.803 | 0.802 | 0.801 | 0.800 |
| **5.5** | **0.797** | 0.804 | 0.804 | 0.803 | 0.802 | 0.802 | 0.801 | 0.800 | 0.800 | 0.799 | 0.798 | 0.798 | 0.796 | 0.795 |
| **6.0** | **0.790** | 0.799 | 0.798 | 0.797 | 0.796 | 0.796 | 0.795 | 0.794 | 0.793 | 0.792 | 0.791 | 0.790 | 0.789 | 0.788 |
| **6.5** | **0.782** | 0.793 | 0.792 | 0.791 | 0.790 | 0.789 | 0.788 | 0.787 | 0.786 | 0.785 | 0.784 | 0.783 | 0.781 | 0.779 |
| **7.0** | **0.772** | 0.786 | 0.784 | 0.783 | 0.782 | 0.781 | 0.780 | 0.778 | 0.777 | 0.776 | 0.775 | 0.773 | 0.771 | 0.770 |
| **7.5** | **0.763** | 0.779 | 0.777 | 0.776 | 0.774 | 0.773 | 0.772 | 0.770 | 0.769 | 0.767 | 0.766 | 0.764 | 0.761 | 0.760 |
| **8.0** | **0.753** | 0.771 | 0.769 | 0.768 | 0.766 | 0.764 | 0.763 | 0.761 | 0.759 | 0.758 | 0.756 | 0.754 | 0.751 | 0.749 |
| **8.5** | **0.742** | 0.764 | 0.762 | 0.760 | 0.758 | 0.756 | 0.754 | 0.752 | 0.750 | 0.748 | 0.746 | 0.744 | 0.741 | 0.739 |
| **9.0** | **0.733** | 0.756 | 0.754 | 0.752 | 0.750 | 0.748 | 0.746 | 0.744 | 0.742 | 0.740 | 0.738 | 0.735 | 0.731 | 0.728 |
| **9.5** | **0.706** | 0.748 | 0.745 | 0.743 | 0.740 | 0.737 | 0.734 | 0.730 | 0.726 | 0.722 | 0.717 | 0.712 | 0.700 | 0.693 |
| **10.0** | **0.646** | 0.731 | 0.726 | 0.721 | 0.716 | 0.711 | 0.702 | 0.694 | 0.685 | 0.677 | 0.666 | 0.656 | 0.635 | 0.623 |
| **10.5** | **0.556** | 0.690 | 0.680 | 0.669 | 0.659 | 0.649 | 0.636 | 0.623 | 0.610 | 0.597 | 0.583 | 0.570 | 0.543 | 0.530 |
| **11.0** | **0.469** | 0.617 | 0.603 | 0.590 | 0.577 | 0.563 | 0.549 | 0.535 | 0.521 | 0.507 | 0.494 | 0.481 | 0.457 | 0.446 |
| **11.5** | **0.396** | 0.536 | 0.522 | 0.507 | 0.493 | 0.478 | 0.466 | 0.453 | 0.440 | 0.427 | 0.417 | 0.406 | 0.387 | 0.378 |
| **12.0** | **0.340** | 0.459 | 0.446 | 0.433 | 0.420 | 0.407 | 0.397 | 0.386 | 0.376 | 0.366 | 0.357 | 0.349 | 0.333 | 0.325 |
| **12.5** | **0.296** | 0.395 | 0.384 | 0.373 | 0.362 | 0.351 | 0.343 | 0.334 | 0.326 | 0.317 | 0.310 | 0.303 | 0.290 | 0.284 |
| **13.0** | **0.260** | 0.343 | 0.334 | 0.325 | 0.316 | 0.307 | 0.299 | 0.292 | 0.285 | 0.278 | 0.272 | 0.266 | 0.255 | 0.250 |
| **13.5** | **0.232** | 0.303 | 0.295 | 0.288 | 0.280 | 0.272 | 0.266 | 0.259 | 0.253 | 0.247 | 0.242 | 0.237 | 0.227 | 0.222 |
| **14.0** | **0.207** | 0.269 | 0.262 | 0.255 | 0.248 | 0.241 | 0.236 | 0.231 | 0.225 | 0.220 | 0.216 | 0.211 | 0.203 | 0.199 |
| **14.5** | **0.185** | 0.239 | 0.234 | 0.228 | 0.222 | 0.216 | 0.211 | 0.207 | 0.202 | 0.197 | 0.193 | 0.189 | 0.182 | 0.178 |
| **15.0** | **0.166** | 0.214 | 0.209 | 0.204 | 0.198 | 0.193 | 0.189 | 0.185 | 0.181 | 0.177 | 0.173 | 0.170 | 0.163 | 0.160 |
| **15.5** | **0.151** | 0.193 | 0.188 | 0.184 | 0.179 | 0.175 | 0.171 | 0.167 | 0.164 | 0.160 | 0.157 | 0.154 | 0.148 | 0.145 |
| **16.0** | **0.137** | 0.175 | 0.171 | 0.167 | 0.163 | 0.159 | 0.155 | 0.152 | 0.149 | 0.146 | 0.143 | 0.140 | 0.135 | 0.132 |
| **16.5** | **0.125** | 0.159 | 0.156 | 0.152 | 0.148 | 0.145 | 0.142 | 0.139 | 0.136 | 0.133 | 0.130 | 0.128 | 0.123 | 0.121 |
| **17.0** | **0.115** | 0.146 | 0.142 | 0.139 | 0.136 | 0.132 | 0.130 | 0.127 | 0.124 | 0.122 | 0.119 | 0.117 | 0.113 | 0.111 |
| **17.5** | **0.106** | 0.134 | 0.131 | 0.128 | 0.125 | 0.122 | 0.119 | 0.117 | 0.114 | 0.112 | 0.110 | 0.108 | 0.104 | 0.102 |
| **18.0** | **0.098** | 0.123 | 0.120 | 0.117 | 0.115 | 0.112 | 0.110 | 0.108 | 0.105 | 0.103 | 0.101 | 0.099 | 0.096 | 0.094 |
| **18.5** | **0.090** | 0.113 | 0.111 | 0.108 | 0.106 | 0.104 | 0.101 | 0.099 | 0.097 | 0.095 | 0.094 | 0.092 | 0.089 | 0.087 |
| **19.0** | **0.083** | 0.104 | 0.102 | 0.100 | 0.098 | 0.095 | 0.094 | 0.092 | 0.090 | 0.088 | 0.086 | 0.085 | 0.082 | 0.081 |
| **19.5** | **0.078** | 0.097 | 0.095 | 0.093 | 0.091 | 0.089 | 0.087 | 0.085 | 0.084 | 0.082 | 0.080 | 0.079 | 0.076 | 0.075 |
| **20.0** | **0.072** | 0.090 | 0.088 | 0.086 | 0.084 | 0.083 | 0.081 | 0.079 | 0.078 | 0.076 | 0.075 | 0.074 | 0.071 | 0.070 |
| **20.5** | **0.068** | 0.084 | 0.082 | 0.081 | 0.079 | 0.077 | 0.076 | 0.074 | 0.073 | 0.071 | 0.070 | 0.069 | 0.067 | 0.065 |
| **21.0** | **0.063** | 0.079 | 0.077 | 0.075 | 0.074 | 0.072 | 0.071 | 0.069 | 0.068 | 0.067 | 0.066 | 0.064 | 0.062 | 0.061 |
| **21.5** | **0.060** | 0.074 | 0.073 | 0.071 | 0.070 | 0.068 | 0.067 | 0.066 | 0.064 | 0.063 | 0.062 | 0.061 | 0.059 | 0.058 |
| **22.0** | **0.056** | 0.070 | 0.068 | 0.067 | 0.065 | 0.064 | 0.063 | 0.062 | 0.061 | 0.059 | 0.058 | 0.057 | 0.056 | 0.055 |
| **22.5** | **0.053** | 0.065 | 0.064 | 0.063 | 0.062 | 0.060 | 0.059 | 0.058 | 0.057 | 0.056 | 0.055 | 0.054 | 0.052 | 0.052 |

*Table 12-2: $C_t$ values, noise mode 0*

### 12.1.3 Noise Curve, Noise Mode 0

| **Sound Power Level at Hub Height, Noise Mode 0 (Blades without optional serrated trailing edge)** | |
|---|---|
| **Conditions for Sound Power Level:** | **Measurement standard IEC 61400-11 ed. 3**<br>**Maximum turbulence at 10 metre height: 16%**<br>**Inflow angle (vertical): 0 ±2°**<br>**Air density: 1.225 kg/m$^3$** |
| **Wind speed at hub height [m/s]** | **Sound Power Level at Hub Height ) [dBA]** |
| **3.0** | 91.7 |
| **4.0** | 92.0 |
| **5.0** | 94.5 |
| **6.0** | 97.4 |
| **7.0** | 101.4 |
| **8.0** | 105.1 |
| **9.0** | 107.9 |
| **10.0** | 108.5 |
| **11.0** | 108.4 |
| **12.0** | 108.4 |
| **13.0** | 108.3 |
| **14.0** | 108.3 |
| **15.0** | 108.2 |
| **16.0** | 108.2 |
| **17.0** | 108.1 |
| **18.0** | 108.1 |
| **19.0** | 108.0 |
| **20.0** | 107.9 |

*Table 12-3: Noise curve, noise mode 0*

### 12.1.4 Noise Curve, Noise Mode $0^+$

| **Sound Power Level at Hub Height, Noise Mode $0^+$ (Blades with optional serrated trailing edge)** | |
|---|---|
| **Conditions for Sound Power Level:** | **Measurement standard IEC 61400-11 ed. 3**<br>**Maximum turbulence at 10 metre height: 16%**<br>**Inflow angle (vertical): 0 ±2°**<br>**Air density: 1.225 kg/m$^3$** |
| **Wind speed at hub height [m/s]** | **Sound Power Level at Hub Height ) [dBA]** |
| **3.0** | 89.4 |
| **4.0** | 89.5 |
| **5.0** | 90.4 |
| **6.0** | 94.3 |
| **7.0** | 97.1 |
| **8.0** | 101.2 |
| **9.0** | 104.2 |
| **10.0** | 104.9 |
| **11.0** | 105.3 |
| **12.0** | 105.5 |
| **13.0** | 105.7 |
| **14.0** | 105.9 |
| **15.0** | 106.0 |
| **16.0** | 106.0 |
| **17.0** | 106.0 |
| **18.0** | 106.0 |
| **19.0** | 106.0 |
| **20.0** | 106.0 |

*Table 12-4: Noise curve, noise mode $0^+$*

## 12.2 Mode 1

### 12.2.1 Power Curves, Noise Mode 1

| Air density [kg/m$^3$] | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Wind speed [m/s]** | **1.225** | **0.95** | **0.975** | **1.0** | **1.025** | **1.05** | **1.075** | **1.1** | **1.125** | **1.15** | **1.175** | **1.2** | **1.25** | **1.275** |
| **3.0** | **30** | 13 | 14 | 16 | 17 | 19 | 20 | 22 | 23 | 25 | 27 | 28 | 32 | 33 |
| **3.5** | **97** | 63 | 66 | 69 | 72 | 75 | 78 | 81 | 84 | 87 | 91 | 94 | 100 | 103 |
| **4.0** | **179** | 128 | 133 | 138 | 142 | 147 | 152 | 156 | 161 | 166 | 170 | 175 | 184 | 189 |
| **4.5** | **278** | 205 | 212 | 219 | 225 | 232 | 239 | 245 | 252 | 259 | 265 | 272 | 285 | 292 |
| **5.0** | **396** | 297 | 306 | 315 | 324 | 333 | 342 | 351 | 360 | 369 | 378 | 387 | 406 | 415 |
| **5.5** | **539** | 407 | 419 | 432 | 444 | 455 | 467 | 479 | 491 | 503 | 515 | 527 | 551 | 563 |
| **6.0** | **711** | 541 | 557 | 572 | 588 | 603 | 619 | 634 | 650 | 665 | 680 | 696 | 726 | 742 |
| **6.5** | **913** | 699 | 718 | 738 | 758 | 777 | 797 | 816 | 836 | 855 | 874 | 894 | 932 | 952 |
| **7.0** | **1150** | 884 | 909 | 933 | 957 | 982 | 1006 | 1030 | 1054 | 1078 | 1102 | 1126 | 1174 | 1198 |
| **7.5** | **1419** | 1096 | 1125 | 1155 | 1185 | 1214 | 1244 | 1273 | 1302 | 1332 | 1361 | 1390 | 1448 | 1478 |
| **8.0** | **1723** | 1336 | 1371 | 1407 | 1443 | 1478 | 1513 | 1549 | 1584 | 1619 | 1654 | 1689 | 1758 | 1792 |
| **8.5** | **2046** | 1595 | 1637 | 1679 | 1720 | 1762 | 1803 | 1844 | 1884 | 1925 | 1965 | 2005 | 2085 | 2125 |
| **9.0** | **2354** | 1849 | 1896 | 1943 | 1989 | 2036 | 2082 | 2128 | 2173 | 2219 | 2264 | 2309 | 2397 | 2441 |
| **9.5** | **2632** | 2083 | 2134 | 2186 | 2237 | 2288 | 2338 | 2388 | 2438 | 2488 | 2536 | 2584 | 2678 | 2724 |
| **10.0** | **2856** | 2288 | 2343 | 2398 | 2453 | 2508 | 2559 | 2611 | 2663 | 2715 | 2762 | 2809 | 2896 | 2937 |
| **10.5** | **3036** | 2498 | 2555 | 2612 | 2668 | 2725 | 2774 | 2823 | 2872 | 2921 | 2959 | 2998 | 3065 | 3095 |
| **11.0** | **3168** | 2728 | 2779 | 2830 | 2881 | 2932 | 2972 | 3011 | 3051 | 3090 | 3116 | 3142 | 3185 | 3203 |
| **11.5** | **3250** | 2939 | 2981 | 3023 | 3064 | 3106 | 3131 | 3157 | 3182 | 3207 | 3221 | 3235 | 3257 | 3265 |
| **12.0** | **3285** | 3114 | 3141 | 3168 | 3194 | 3221 | 3233 | 3246 | 3258 | 3270 | 3275 | 3280 | 3288 | 3290 |
| **12.5** | **3297** | 3226 | 3238 | 3251 | 3264 | 3277 | 3281 | 3285 | 3289 | 3293 | 3294 | 3296 | 3297 | 3298 |
| **13.0** | **3300** | 3279 | 3283 | 3287 | 3291 | 3295 | 3296 | 3297 | 3298 | 3299 | 3299 | 3299 | 3300 | 3300 |
| **13.5** | **3300** | 3288 | 3290 | 3292 | 3294 | 3296 | 3297 | 3298 | 3299 | 3300 | 3300 | 3300 | 3300 | 3300 |
| **14.0** | **3300** | 3296 | 3297 | 3298 | 3299 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 |
| **14.5** | **3300** | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 |
| **15.0** | **3300** | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 |
| **15.5** | **3300** | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 |
| **16.0** | **3300** | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 |
| **16.5** | **3300** | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 |
| **17.0** | **3300** | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 |
| **17.5** | **3300** | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 |
| **18.0** | **3300** | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 |
| **18.5** | **3300** | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 |
| **19.0** | **3300** | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 |
| **19.5** | **3300** | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 |
| **20.0** | **3300** | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 |
| **20.5** | **3300** | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 |
| **21.0** | **3300** | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 |
| **21.5** | **3300** | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 |
| **22.0** | **3300** | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 |
| **22.5** | **3300** | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 | 3300 |

*Table 12-5: Power curve, noise mode 1*

### 12.2.2 $C_t$ Values, Noise Mode 1

| Air density kg/m$^3$ | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Wind speed [m/s]** | **1.225** | **0.950** | **0.975** | **1.0** | **1.025** | **1.05** | **1.075** | **1.1** | **1.125** | **1.15** | **1.175** | **1.2** | **1.25** | **1.275** |
| **3.0** | **0.918** | 0.927 | 0.926 | 0.925 | 0.924 | 0.924 | 0.923 | 0.922 | 0.921 | 0.920 | 0.920 | 0.919 | 0.917 | 0.917 |
| **3.5** | **0.886** | 0.893 | 0.892 | 0.892 | 0.891 | 0.890 | 0.890 | 0.889 | 0.889 | 0.888 | 0.887 | 0.887 | 0.885 | 0.885 |
| **4.0** | **0.844** | 0.850 | 0.850 | 0.849 | 0.849 | 0.848 | 0.847 | 0.847 | 0.846 | 0.846 | 0.845 | 0.845 | 0.843 | 0.843 |
| **4.5** | **0.814** | 0.820 | 0.819 | 0.819 | 0.818 | 0.817 | 0.817 | 0.816 | 0.816 | 0.815 | 0.815 | 0.814 | 0.814 | 0.813 |
| **5.0** | **0.801** | 0.807 | 0.807 | 0.806 | 0.806 | 0.805 | 0.805 | 0.804 | 0.804 | 0.803 | 0.803 | 0.802 | 0.801 | 0.800 |
| **5.5** | **0.797** | 0.804 | 0.804 | 0.803 | 0.802 | 0.802 | 0.801 | 0.800 | 0.800 | 0.799 | 0.798 | 0.798 | 0.796 | 0.795 |
| **6.0** | **0.790** | 0.799 | 0.798 | 0.797 | 0.796 | 0.796 | 0.795 | 0.794 | 0.793 | 0.792 | 0.791 | 0.790 | 0.789 | 0.788 |
| **6.5** | **0.782** | 0.793 | 0.792 | 0.791 | 0.790 | 0.789 | 0.788 | 0.787 | 0.786 | 0.785 | 0.784 | 0.783 | 0.781 | 0.779 |
| **7.0** | **0.772** | 0.786 | 0.784 | 0.783 | 0.782 | 0.781 | 0.780 | 0.778 | 0.777 | 0.776 | 0.775 | 0.773 | 0.771 | 0.770 |
| **7.5** | **0.763** | 0.779 | 0.777 | 0.776 | 0.774 | 0.773 | 0.772 | 0.770 | 0.769 | 0.767 | 0.766 | 0.764 | 0.761 | 0.760 |
| **8.0** | **0.752** | 0.770 | 0.769 | 0.767 | 0.765 | 0.764 | 0.762 | 0.760 | 0.759 | 0.757 | 0.755 | 0.754 | 0.750 | 0.749 |
| **8.5** | **0.729** | 0.749 | 0.747 | 0.746 | 0.744 | 0.742 | 0.740 | 0.738 | 0.737 | 0.735 | 0.733 | 0.731 | 0.727 | 0.726 |
| **9.0** | **0.685** | 0.705 | 0.704 | 0.702 | 0.700 | 0.698 | 0.696 | 0.694 | 0.693 | 0.691 | 0.689 | 0.687 | 0.683 | 0.681 |
| **9.5** | **0.627** | 0.649 | 0.647 | 0.645 | 0.643 | 0.641 | 0.639 | 0.638 | 0.636 | 0.634 | 0.632 | 0.630 | 0.625 | 0.622 |
| **10.0** | **0.559** | 0.584 | 0.583 | 0.581 | 0.579 | 0.577 | 0.575 | 0.573 | 0.571 | 0.569 | 0.566 | 0.563 | 0.555 | 0.551 |
| **10.5** | **0.497** | 0.533 | 0.531 | 0.529 | 0.526 | 0.524 | 0.521 | 0.518 | 0.514 | 0.511 | 0.506 | 0.501 | 0.491 | 0.484 |
| **11.0** | **0.439** | 0.495 | 0.491 | 0.487 | 0.483 | 0.479 | 0.474 | 0.469 | 0.464 | 0.459 | 0.452 | 0.446 | 0.432 | 0.425 |
| **11.5** | **0.386** | 0.459 | 0.453 | 0.447 | 0.442 | 0.436 | 0.429 | 0.422 | 0.415 | 0.408 | 0.401 | 0.394 | 0.379 | 0.371 |
| **12.0** | **0.338** | 0.422 | 0.414 | 0.407 | 0.399 | 0.392 | 0.384 | 0.376 | 0.368 | 0.360 | 0.353 | 0.345 | 0.331 | 0.324 |
| **12.5** | **0.296** | 0.381 | 0.373 | 0.364 | 0.356 | 0.347 | 0.339 | 0.332 | 0.324 | 0.316 | 0.309 | 0.302 | 0.289 | 0.283 |
| **13.0** | **0.260** | 0.340 | 0.331 | 0.323 | 0.314 | 0.306 | 0.299 | 0.292 | 0.285 | 0.278 | 0.272 | 0.266 | 0.255 | 0.250 |
| **13.5** | **0.232** | 0.301 | 0.294 | 0.286 | 0.279 | 0.271 | 0.265 | 0.259 | 0.253 | 0.247 | 0.242 | 0.237 | 0.227 | 0.222 |
| **14.0** | **0.207** | 0.268 | 0.261 | 0.255 | 0.248 | 0.241 | 0.236 | 0.231 | 0.225 | 0.220 | 0.216 | 0.211 | 0.203 | 0.199 |
| **14.5** | **0.185** | 0.239 | 0.234 | 0.228 | 0.222 | 0.216 | 0.211 | 0.207 | 0.202 | 0.197 | 0.193 | 0.189 | 0.182 | 0.178 |
| **15.0** | **0.166** | 0.214 | 0.209 | 0.204 | 0.198 | 0.193 | 0.189 | 0.185 | 0.181 | 0.177 | 0.173 | 0.170 | 0.163 | 0.160 |
| **15.5** | **0.151** | 0.193 | 0.188 | 0.184 | 0.179 | 0.175 | 0.171 | 0.167 | 0.164 | 0.160 | 0.157 | 0.154 | 0.148 | 0.145 |
| **16.0** | **0.137** | 0.175 | 0.171 | 0.167 | 0.163 | 0.159 | 0.155 | 0.152 | 0.149 | 0.146 | 0.143 | 0.140 | 0.135 | 0.132 |
| **16.5** | **0.125** | 0.159 | 0.156 | 0.152 | 0.148 | 0.145 | 0.142 | 0.139 | 0.136 | 0.133 | 0.130 | 0.128 | 0.123 | 0.121 |
| **17.0** | **0.115** | 0.146 | 0.142 | 0.139 | 0.136 | 0.132 | 0.130 | 0.127 | 0.124 | 0.122 | 0.119 | 0.117 | 0.113 | 0.111 |
| **17.5** | **0.106** | 0.134 | 0.131 | 0.128 | 0.125 | 0.122 | 0.119 | 0.117 | 0.114 | 0.112 | 0.110 | 0.108 | 0.104 | 0.102 |
| **18.0** | **0.098** | 0.123 | 0.120 | 0.117 | 0.115 | 0.112 | 0.110 | 0.108 | 0.105 | 0.103 | 0.101 | 0.099 | 0.096 | 0.094 |
| **18.5** | **0.090** | 0.113 | 0.111 | 0.108 | 0.106 | 0.104 | 0.101 | 0.099 | 0.097 | 0.095 | 0.094 | 0.092 | 0.089 | 0.087 |
| **19.0** | **0.083** | 0.104 | 0.102 | 0.100 | 0.098 | 0.095 | 0.094 | 0.092 | 0.090 | 0.088 | 0.086 | 0.085 | 0.082 | 0.081 |
| **19.5** | **0.078** | 0.097 | 0.095 | 0.093 | 0.091 | 0.089 | 0.087 | 0.085 | 0.084 | 0.082 | 0.080 | 0.079 | 0.076 | 0.075 |
| **20.0** | **0.072** | 0.090 | 0.088 | 0.086 | 0.084 | 0.083 | 0.081 | 0.079 | 0.078 | 0.076 | 0.075 | 0.074 | 0.071 | 0.070 |
| **20.5** | **0.068** | 0.084 | 0.082 | 0.081 | 0.079 | 0.077 | 0.076 | 0.074 | 0.073 | 0.071 | 0.070 | 0.069 | 0.067 | 0.065 |
| **21.0** | **0.063** | 0.079 | 0.077 | 0.075 | 0.074 | 0.072 | 0.071 | 0.069 | 0.068 | 0.067 | 0.066 | 0.064 | 0.062 | 0.061 |
| **21.5** | **0.060** | 0.074 | 0.073 | 0.071 | 0.070 | 0.068 | 0.067 | 0.066 | 0.064 | 0.063 | 0.062 | 0.061 | 0.059 | 0.058 |
| **22.0** | **0.056** | 0.070 | 0.068 | 0.067 | 0.065 | 0.064 | 0.063 | 0.062 | 0.061 | 0.059 | 0.058 | 0.057 | 0.056 | 0.055 |
| **22.5** | **0.053** | 0.065 | 0.064 | 0.063 | 0.062 | 0.060 | 0.059 | 0.058 | 0.057 | 0.056 | 0.055 | 0.054 | 0.052 | 0.052 |

*Table 12-6: $C_t$ values, noise mode 1*

### 12.2.3 Noise Curve, Noise Mode 1

| Sound Power Level at Hub Height, Noise Mode 1 (Blades with optional serrated trailing edge) | |
|---|---|
| **Conditions for Sound Power Level:** | **Measurement standard IEC 61400-11 ed. 3**<br>**Maximum turbulence at 10 metre height: 16%**<br>**Inflow angle (vertical): 0 ±2°**<br>**Air density: 1.225 kg/m$^3$** |
| **Wind speed at hub height [m/s]** | **Sound Power Level at Hub Height ) [dBA]** |
| **3.0** | 89.4 |
| **4.0** | 89.5 |
| **5.0** | 90.4 |
| **6.0** | 94.3 |
| **7.0** | 97.1 |
| **8.0** | 101.1 |
| **9.0** | 103.4 |
| **10.0** | 104.3 |
| **11.0** | 104.8 |
| **12.0** | 105.5 |
| **13.0** | 105.7 |
| **14.0** | 105.9 |
| **15.0** | 106.0 |
| **16.0** | 106.0 |
| **17.0** | 106.0 |
| **18.0** | 106.0 |
| **19.0** | 106.0 |
| **20.0** | 106.0 |

*Table 12-7: Noise curve, noise mode 1*

## 12.3 Mode 2

### 12.3.1 Power Curves, Noise Mode 2

| Air density [kg/m$^3$] | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Wind speed [m/s]** | **1.225** | **0.95** | **0.975** | **1.0** | **1.025** | **1.05** | **1.075** | **1.1** | **1.125** | **1.15** | **1.175** | **1.2** | **1.25** | **1.275** |
| **3.0** | **30** | 13 | 14 | 16 | 17 | 19 | 20 | 22 | 23 | 25 | 27 | 28 | 32 | 33 |
| **3.5** | **97** | 63 | 66 | 69 | 72 | 75 | 78 | 81 | 84 | 87 | 91 | 94 | 100 | 103 |
| **4.0** | **179** | 128 | 133 | 138 | 142 | 147 | 152 | 156 | 161 | 166 | 170 | 175 | 184 | 189 |
| **4.5** | **278** | 205 | 212 | 219 | 225 | 232 | 239 | 245 | 252 | 259 | 265 | 272 | 285 | 292 |
| **5.0** | **396** | 297 | 306 | 315 | 324 | 333 | 342 | 351 | 360 | 369 | 378 | 387 | 405 | 415 |
| **5.5** | **539** | 407 | 419 | 431 | 443 | 455 | 467 | 479 | 491 | 503 | 515 | 527 | 551 | 563 |
| **6.0** | **711** | 541 | 557 | 572 | 588 | 603 | 619 | 634 | 649 | 665 | 680 | 696 | 726 | 742 |
| **6.5** | **913** | 698 | 718 | 738 | 757 | 777 | 796 | 816 | 835 | 855 | 874 | 893 | 932 | 951 |
| **7.0** | **1146** | 882 | 906 | 931 | 955 | 979 | 1003 | 1027 | 1051 | 1075 | 1099 | 1123 | 1170 | 1194 |
| **7.5** | **1403** | 1085 | 1114 | 1143 | 1172 | 1201 | 1230 | 1259 | 1288 | 1317 | 1345 | 1374 | 1431 | 1460 |
| **8.0** | **1672** | 1300 | 1335 | 1369 | 1403 | 1437 | 1471 | 1505 | 1539 | 1573 | 1606 | 1639 | 1705 | 1738 |
| **8.5** | **1944** | 1520 | 1560 | 1599 | 1638 | 1677 | 1716 | 1754 | 1793 | 1831 | 1869 | 1906 | 1981 | 2018 |
| **9.0** | **2213** | 1741 | 1785 | 1828 | 1872 | 1916 | 1959 | 2002 | 2045 | 2088 | 2129 | 2171 | 2254 | 2295 |
| **9.5** | **2470** | 1964 | 2013 | 2061 | 2109 | 2158 | 2204 | 2250 | 2296 | 2342 | 2385 | 2427 | 2508 | 2546 |
| **10.0** | **2689** | 2198 | 2249 | 2301 | 2353 | 2405 | 2449 | 2494 | 2539 | 2584 | 2619 | 2654 | 2717 | 2745 |
| **10.5** | **2846** | 2441 | 2491 | 2541 | 2591 | 2640 | 2675 | 2709 | 2744 | 2778 | 2801 | 2823 | 2861 | 2876 |
| **11.0** | **2946** | 2656 | 2697 | 2738 | 2779 | 2820 | 2844 | 2867 | 2890 | 2913 | 2924 | 2935 | 2952 | 2958 |
| **11.5** | **3000** | 2834 | 2862 | 2890 | 2918 | 2946 | 2956 | 2967 | 2978 | 2989 | 2992 | 2996 | 3001 | 3003 |
| **12.0** | **3036** | 2955 | 2971 | 2986 | 3001 | 3017 | 3021 | 3025 | 3029 | 3033 | 3034 | 3035 | 3037 | 3037 |
| **12.5** | **3068** | 3026 | 3034 | 3042 | 3050 | 3059 | 3061 | 3062 | 3064 | 3066 | 3067 | 3067 | 3068 | 3068 |
| **13.0** | **3094** | 3060 | 3067 | 3073 | 3079 | 3085 | 3087 | 3089 | 3091 | 3092 | 3093 | 3093 | 3094 | 3094 |
| **13.5** | **3120** | 3098 | 3102 | 3106 | 3110 | 3114 | 3116 | 3117 | 3118 | 3119 | 3119 | 3120 | 3120 | 3120 |
| **14.0** | **3138** | 3107 | 3112 | 3118 | 3123 | 3129 | 3131 | 3132 | 3134 | 3136 | 3136 | 3137 | 3138 | 3138 |
| **14.5** | **3151** | 3113 | 3120 | 3127 | 3133 | 3140 | 3142 | 3144 | 3146 | 3148 | 3149 | 3150 | 3151 | 3152 |
| **15.0** | **3157** | 3175 | 3175 | 3175 | 3175 | 3175 | 3175 | 3145 | 3149 | 3152 | 3154 | 3155 | 3158 | 3158 |
| **15.5** | **3163** | 3175 | 3175 | 3175 | 3175 | 3175 | 3175 | 3152 | 3156 | 3159 | 3160 | 3162 | 3164 | 3164 |
| **16.0** | **3167** | 3175 | 3175 | 3175 | 3175 | 3175 | 3175 | 3159 | 3162 | 3164 | 3165 | 3166 | 3168 | 3168 |
| **16.5** | **3170** | 3175 | 3175 | 3175 | 3175 | 3175 | 3175 | 3165 | 3166 | 3168 | 3169 | 3170 | 3170 | 3171 |
| **17.0** | **3172** | 3175 | 3175 | 3175 | 3175 | 3175 | 3175 | 3168 | 3170 | 3171 | 3171 | 3172 | 3172 | 3172 |
| **17.5** | **3173** | 3175 | 3175 | 3175 | 3175 | 3175 | 3175 | 3170 | 3171 | 3172 | 3172 | 3173 | 3173 | 3174 |
| **18.0** | **3174** | 3175 | 3175 | 3175 | 3175 | 3175 | 3175 | 3172 | 3173 | 3174 | 3174 | 3174 | 3174 | 3174 |
| **18.5** | **3174** | 3175 | 3175 | 3175 | 3175 | 3175 | 3175 | 3174 | 3174 | 3174 | 3174 | 3174 | 3175 | 3175 |
| **19.0** | **3175** | 3175 | 3175 | 3175 | 3175 | 3175 | 3175 | 3175 | 3175 | 3175 | 3175 | 3175 | 3175 | 3175 |
| **19.5** | **3175** | 3175 | 3175 | 3175 | 3175 | 3175 | 3175 | 3175 | 3175 | 3175 | 3175 | 3175 | 3175 | 3175 |
| **20.0** | **3175** | 3175 | 3175 | 3175 | 3175 | 3175 | 3175 | 3175 | 3175 | 3175 | 3175 | 3175 | 3175 | 3175 |
| **20.5** | **3175** | 3175 | 3175 | 3175 | 3175 | 3175 | 3175 | 3175 | 3175 | 3175 | 3175 | 3175 | 3175 | 3175 |
| **21.0** | **3175** | 3175 | 3175 | 3175 | 3175 | 3175 | 3175 | 3175 | 3175 | 3175 | 3175 | 3175 | 3175 | 3175 |
| **21.5** | **3175** | 3175 | 3175 | 3175 | 3175 | 3175 | 3175 | 3175 | 3175 | 3175 | 3175 | 3175 | 3175 | 3175 |
| **22.0** | **3175** | 3175 | 3175 | 3175 | 3175 | 3175 | 3175 | 3175 | 3175 | 3175 | 3175 | 3175 | 3175 | 3175 |
| **22.5** | **3175** | 3175 | 3175 | 3175 | 3175 | 3175 | 3175 | 3175 | 3175 | 3175 | 3175 | 3175 | 3175 | 3175 |

*Table 12-8: Power curve, noise mode 2*

### 12.3.2 $C_t$ Values, Noise Mode 2

| Air density kg/m$^3$ | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Wind speed [m/s]** | **1.225** | **0.950** | **0.975** | **1.0** | **1.025** | **1.05** | **1.075** | **1.1** | **1.125** | **1.15** | **1.175** | **1.2** | **1.25** | **1.275** |
| **3.0** | **0.918** | 0.927 | 0.926 | 0.925 | 0.924 | 0.924 | 0.923 | 0.922 | 0.921 | 0.920 | 0.920 | 0.919 | 0.917 | 0.917 |
| **3.5** | **0.886** | 0.893 | 0.892 | 0.892 | 0.891 | 0.890 | 0.890 | 0.889 | 0.889 | 0.888 | 0.887 | 0.887 | 0.885 | 0.885 |
| **4.0** | **0.844** | 0.850 | 0.850 | 0.849 | 0.849 | 0.848 | 0.847 | 0.847 | 0.846 | 0.846 | 0.845 | 0.845 | 0.843 | 0.843 |
| **4.5** | **0.814** | 0.820 | 0.819 | 0.819 | 0.818 | 0.817 | 0.817 | 0.816 | 0.816 | 0.815 | 0.815 | 0.814 | 0.813 | 0.813 |
| **5.0** | **0.801** | 0.807 | 0.807 | 0.806 | 0.806 | 0.805 | 0.805 | 0.804 | 0.804 | 0.803 | 0.802 | 0.802 | 0.801 | 0.800 |
| **5.5** | **0.797** | 0.804 | 0.804 | 0.803 | 0.802 | 0.802 | 0.801 | 0.800 | 0.800 | 0.799 | 0.798 | 0.797 | 0.796 | 0.795 |
| **6.0** | **0.789** | 0.799 | 0.798 | 0.797 | 0.796 | 0.795 | 0.795 | 0.794 | 0.793 | 0.792 | 0.791 | 0.790 | 0.789 | 0.788 |
| **6.5** | **0.779** | 0.791 | 0.790 | 0.789 | 0.788 | 0.787 | 0.786 | 0.785 | 0.784 | 0.783 | 0.781 | 0.780 | 0.778 | 0.777 |
| **7.0** | **0.763** | 0.776 | 0.775 | 0.774 | 0.772 | 0.771 | 0.770 | 0.769 | 0.768 | 0.766 | 0.765 | 0.764 | 0.762 | 0.760 |
| **7.5** | **0.735** | 0.750 | 0.749 | 0.747 | 0.746 | 0.745 | 0.743 | 0.742 | 0.740 | 0.739 | 0.738 | 0.736 | 0.733 | 0.732 |
| **8.0** | **0.696** | 0.712 | 0.710 | 0.709 | 0.708 | 0.706 | 0.705 | 0.703 | 0.702 | 0.700 | 0.699 | 0.697 | 0.695 | 0.693 |
| **8.5** | **0.651** | 0.667 | 0.665 | 0.664 | 0.662 | 0.661 | 0.660 | 0.658 | 0.657 | 0.655 | 0.654 | 0.652 | 0.649 | 0.648 |
| **9.0** | **0.605** | 0.620 | 0.619 | 0.618 | 0.616 | 0.615 | 0.614 | 0.612 | 0.611 | 0.609 | 0.608 | 0.607 | 0.604 | 0.602 |
| **9.5** | **0.559** | 0.579 | 0.577 | 0.576 | 0.575 | 0.573 | 0.572 | 0.570 | 0.568 | 0.566 | 0.564 | 0.562 | 0.556 | 0.553 |
| **10.0** | **0.509** | 0.544 | 0.542 | 0.540 | 0.538 | 0.537 | 0.533 | 0.530 | 0.527 | 0.524 | 0.519 | 0.514 | 0.503 | 0.497 |
| **10.5** | **0.455** | 0.514 | 0.511 | 0.507 | 0.504 | 0.501 | 0.495 | 0.489 | 0.483 | 0.477 | 0.469 | 0.462 | 0.447 | 0.439 |
| **11.0** | **0.400** | 0.478 | 0.473 | 0.467 | 0.462 | 0.456 | 0.449 | 0.441 | 0.433 | 0.426 | 0.417 | 0.409 | 0.392 | 0.384 |
| **11.5** | **0.349** | 0.440 | 0.432 | 0.425 | 0.417 | 0.409 | 0.401 | 0.392 | 0.383 | 0.374 | 0.366 | 0.358 | 0.342 | 0.334 |
| **12.0** | **0.306** | 0.397 | 0.388 | 0.379 | 0.371 | 0.362 | 0.354 | 0.345 | 0.337 | 0.328 | 0.321 | 0.314 | 0.300 | 0.293 |
| **12.5** | **0.271** | 0.353 | 0.345 | 0.336 | 0.328 | 0.319 | 0.312 | 0.304 | 0.297 | 0.289 | 0.283 | 0.277 | 0.265 | 0.259 |
| **13.0** | **0.241** | 0.313 | 0.305 | 0.298 | 0.290 | 0.283 | 0.276 | 0.270 | 0.263 | 0.257 | 0.252 | 0.246 | 0.236 | 0.231 |
| **13.5** | **0.217** | 0.281 | 0.274 | 0.267 | 0.260 | 0.254 | 0.248 | 0.242 | 0.237 | 0.231 | 0.226 | 0.221 | 0.212 | 0.208 |
| **14.0** | **0.195** | 0.250 | 0.244 | 0.239 | 0.233 | 0.227 | 0.222 | 0.217 | 0.212 | 0.207 | 0.203 | 0.199 | 0.191 | 0.187 |
| **14.5** | **0.176** | 0.224 | 0.219 | 0.214 | 0.209 | 0.204 | 0.200 | 0.195 | 0.191 | 0.187 | 0.183 | 0.179 | 0.172 | 0.169 |
| **15.0** | **0.158** | 0.200 | 0.196 | 0.191 | 0.187 | 0.183 | 0.179 | 0.175 | 0.172 | 0.168 | 0.165 | 0.161 | 0.155 | 0.152 |
| **15.5** | **0.144** | 0.181 | 0.177 | 0.173 | 0.170 | 0.166 | 0.162 | 0.159 | 0.156 | 0.152 | 0.150 | 0.147 | 0.141 | 0.139 |
| **16.0** | **0.131** | 0.165 | 0.161 | 0.158 | 0.154 | 0.151 | 0.148 | 0.145 | 0.142 | 0.139 | 0.136 | 0.134 | 0.129 | 0.126 |
| **16.5** | **0.120** | 0.151 | 0.148 | 0.144 | 0.141 | 0.138 | 0.135 | 0.133 | 0.130 | 0.127 | 0.125 | 0.122 | 0.118 | 0.116 |
| **17.0** | **0.110** | 0.139 | 0.136 | 0.133 | 0.130 | 0.127 | 0.124 | 0.122 | 0.119 | 0.117 | 0.114 | 0.112 | 0.108 | 0.106 |
| **17.5** | **0.101** | 0.127 | 0.125 | 0.122 | 0.119 | 0.116 | 0.114 | 0.112 | 0.109 | 0.107 | 0.105 | 0.103 | 0.100 | 0.098 |
| **18.0** | **0.094** | 0.118 | 0.115 | 0.112 | 0.110 | 0.107 | 0.105 | 0.103 | 0.101 | 0.099 | 0.097 | 0.095 | 0.092 | 0.090 |
| **18.5** | **0.087** | 0.109 | 0.106 | 0.104 | 0.102 | 0.099 | 0.097 | 0.095 | 0.093 | 0.091 | 0.090 | 0.088 | 0.085 | 0.084 |
| **19.0** | **0.080** | 0.100 | 0.098 | 0.096 | 0.094 | 0.092 | 0.090 | 0.088 | 0.086 | 0.084 | 0.083 | 0.081 | 0.079 | 0.077 |
| **19.5** | **0.074** | 0.093 | 0.091 | 0.089 | 0.087 | 0.085 | 0.083 | 0.082 | 0.080 | 0.079 | 0.077 | 0.076 | 0.073 | 0.072 |
| **20.0** | **0.069** | 0.087 | 0.085 | 0.083 | 0.081 | 0.079 | 0.078 | 0.076 | 0.075 | 0.073 | 0.072 | 0.071 | 0.068 | 0.067 |
| **20.5** | **0.065** | 0.081 | 0.079 | 0.077 | 0.076 | 0.074 | 0.073 | 0.071 | 0.070 | 0.068 | 0.067 | 0.066 | 0.064 | 0.063 |
| **21.0** | **0.061** | 0.075 | 0.074 | 0.072 | 0.071 | 0.069 | 0.068 | 0.067 | 0.065 | 0.064 | 0.063 | 0.062 | 0.060 | 0.059 |
| **21.5** | **0.058** | 0.071 | 0.070 | 0.068 | 0.067 | 0.065 | 0.064 | 0.063 | 0.062 | 0.061 | 0.060 | 0.059 | 0.057 | 0.056 |
| **22.0** | **0.054** | 0.067 | 0.066 | 0.064 | 0.063 | 0.061 | 0.060 | 0.059 | 0.058 | 0.057 | 0.056 | 0.055 | 0.053 | 0.052 |
| **22.5** | **0.051** | 0.063 | 0.062 | 0.060 | 0.059 | 0.058 | 0.057 | 0.056 | 0.055 | 0.054 | 0.053 | 0.052 | 0.050 | 0.049 |

*Table 12-9: $C_t$ values, noise mode 2*

### 12.3.3 Noise Curve, Noise Mode 2

| **Sound Power Level at Hub Height, Noise Mode 2 (Blades with optional serrated trailing edge)** | |
|---|---|
| **Conditions for Sound Power Level:** | **Measurement standard IEC 61400-11 ed. 3**<br>**Maximum turbulence at 10 metre height: 16%**<br>**Inflow angle (vertical): 0 ±2°**<br>**Air density: 1.225 kg/m$^3$** |
| **Wind speed at hub height [m/s]** | **Sound Power Level at Hub Height ) [dBA]** |
| **3.0** | 89.4 |
| **4.0** | 89.5 |
| **5.0** | 90.4 |
| **6.0** | 94.3 |
| **7.0** | 97.1 |
| **8.0** | 100.9 |
| **9.0** | 101.8 |
| **10.0** | 102.5 |
| **11.0** | 103.1 |
| **12.0** | 103.8 |
| **13.0** | 104.2 |
| **14.0** | 104.5 |
| **15.0** | 104.5 |
| **16.0** | 104.5 |
| **17.0** | 104.5 |
| **18.0** | 104.5 |
| **19.0** | 104.5 |
| **20.0** | 104.5 |

*Table 12-10: Noise curve, noise mode 2*

## 12.4 Mode 3

### 12.4.1 Power Curves, Noise Mode 3

| Air density [kg/m$^3$] | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Wind speed [m/s]** | **1.225** | **0.95** | **0.975** | **1.0** | **1.025** | **1.05** | **1.075** | **1.1** | **1.125** | **1.15** | **1.175** | **1.2** | **1.25** | **1.275** |
| **3.0** | **30** | 13 | 14 | 16 | 17 | 19 | 20 | 22 | 23 | 25 | 27 | 28 | 32 | 33 |
| **3.5** | **97** | 63 | 66 | 69 | 72 | 75 | 78 | 81 | 84 | 87 | 91 | 94 | 100 | 103 |
| **4.0** | **179** | 128 | 133 | 138 | 142 | 147 | 152 | 156 | 161 | 166 | 170 | 175 | 184 | 189 |
| **4.5** | **278** | 205 | 212 | 219 | 225 | 232 | 239 | 245 | 252 | 259 | 265 | 272 | 285 | 292 |
| **5.0** | **396** | 297 | 306 | 315 | 324 | 333 | 342 | 351 | 360 | 369 | 378 | 387 | 405 | 414 |
| **5.5** | **535** | 405 | 417 | 429 | 440 | 452 | 464 | 476 | 488 | 500 | 511 | 523 | 547 | 558 |
| **6.0** | **696** | 531 | 546 | 561 | 576 | 591 | 606 | 621 | 636 | 651 | 666 | 681 | 711 | 725 |
| **6.5** | **873** | 671 | 690 | 708 | 727 | 745 | 764 | 782 | 800 | 819 | 837 | 855 | 891 | 909 |
| **7.0** | **1062** | 822 | 844 | 866 | 888 | 910 | 932 | 954 | 976 | 997 | 1019 | 1041 | 1084 | 1105 |
| **7.5** | **1252** | 974 | 999 | 1025 | 1051 | 1076 | 1102 | 1127 | 1152 | 1177 | 1202 | 1227 | 1277 | 1302 |
| **8.0** | **1457** | 1137 | 1166 | 1196 | 1225 | 1255 | 1284 | 1313 | 1342 | 1371 | 1400 | 1429 | 1486 | 1514 |
| **8.5** | **1688** | 1320 | 1354 | 1388 | 1422 | 1456 | 1489 | 1523 | 1556 | 1589 | 1622 | 1655 | 1720 | 1752 |
| **9.0** | **1939** | 1522 | 1561 | 1600 | 1639 | 1678 | 1716 | 1753 | 1791 | 1829 | 1865 | 1902 | 1973 | 2008 |
| **9.5** | **2182** | 1735 | 1778 | 1821 | 1864 | 1907 | 1947 | 1987 | 2028 | 2068 | 2106 | 2144 | 2216 | 2250 |
| **10.0** | **2410** | 1970 | 2016 | 2061 | 2106 | 2152 | 2192 | 2233 | 2273 | 2314 | 2346 | 2378 | 2435 | 2460 |
| **10.5** | **2572** | 2205 | 2250 | 2295 | 2340 | 2385 | 2417 | 2448 | 2480 | 2511 | 2531 | 2552 | 2586 | 2600 |
| **11.0** | **2675** | 2416 | 2453 | 2490 | 2527 | 2564 | 2584 | 2605 | 2625 | 2646 | 2655 | 2665 | 2680 | 2685 |
| **11.5** | **2733** | 2593 | 2617 | 2640 | 2664 | 2688 | 2697 | 2706 | 2715 | 2724 | 2727 | 2730 | 2734 | 2735 |
| **12.0** | **2777** | 2710 | 2723 | 2735 | 2748 | 2760 | 2764 | 2767 | 2770 | 2774 | 2775 | 2776 | 2777 | 2778 |
| **12.5** | **2818** | 2787 | 2793 | 2799 | 2805 | 2811 | 2812 | 2814 | 2815 | 2816 | 2817 | 2817 | 2818 | 2818 |
| **13.0** | **2856** | 2842 | 2845 | 2847 | 2850 | 2853 | 2854 | 2854 | 2855 | 2855 | 2855 | 2856 | 2856 | 2856 |
| **13.5** | **2894** | 2885 | 2887 | 2889 | 2890 | 2892 | 2893 | 2893 | 2893 | 2893 | 2893 | 2893 | 2893 | 2894 |
| **14.0** | **2922** | 2918 | 2919 | 2920 | 2921 | 2922 | 2922 | 2922 | 2922 | 2922 | 2922 | 2922 | 2922 | 2922 |
| **14.5** | **2944** | 2942 | 2942 | 2943 | 2943 | 2943 | 2943 | 2943 | 2944 | 2944 | 2944 | 2944 | 2944 | 2944 |
| **15.0** | **2956** | 2954 | 2955 | 2955 | 2955 | 2956 | 2956 | 2956 | 2956 | 2956 | 2956 | 2956 | 2956 | 2956 |
| **15.5** | **2965** | 2964 | 2965 | 2965 | 2965 | 2965 | 2965 | 2965 | 2965 | 2965 | 2965 | 2965 | 2965 | 2965 |
| **16.0** | **2971** | 2970 | 2970 | 2971 | 2971 | 2971 | 2971 | 2971 | 2971 | 2971 | 2971 | 2971 | 2971 | 2971 |
| **16.5** | **2974** | 2974 | 2974 | 2974 | 2974 | 2974 | 2974 | 2974 | 2974 | 2974 | 2974 | 2974 | 2974 | 2974 |
| **17.0** | **2976** | 2976 | 2976 | 2976 | 2976 | 2976 | 2976 | 2976 | 2976 | 2976 | 2976 | 2976 | 2976 | 2976 |
| **17.5** | **2978** | 2978 | 2978 | 2978 | 2978 | 2978 | 2978 | 2978 | 2978 | 2978 | 2978 | 2978 | 2978 | 2978 |
| **18.0** | **2979** | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 |
| **18.5** | **2979** | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 |
| **19.0** | **2979** | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 |
| **19.5** | **2979** | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 |
| **20.0** | **2979** | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 |
| **20.5** | **2979** | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 |
| **21.0** | **2979** | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 |
| **21.5** | **2979** | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 |
| **22.0** | **2979** | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 |
| **22.5** | **2979** | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 | 2979 |

*Table 12-11: Power curve, noise mode 3*

### 12.4.2 $C_t$ Values, Noise Mode 3

| Air density kg/m$^3$ | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Wind speed [m/s]** | **1.225** | **0.950** | **0.975** | **1.0** | **1.025** | **1.05** | **1.075** | **1.1** | **1.125** | **1.15** | **1.175** | **1.2** | **1.25** | **1.275** |
| **3.0** | **0.918** | 0.927 | 0.926 | 0.925 | 0.924 | 0.924 | 0.923 | 0.922 | 0.921 | 0.920 | 0.920 | 0.919 | 0.917 | 0.917 |
| **3.5** | **0.886** | 0.893 | 0.892 | 0.892 | 0.891 | 0.890 | 0.890 | 0.889 | 0.889 | 0.888 | 0.887 | 0.887 | 0.885 | 0.885 |
| **4.0** | **0.844** | 0.850 | 0.850 | 0.849 | 0.849 | 0.848 | 0.847 | 0.847 | 0.846 | 0.846 | 0.845 | 0.845 | 0.843 | 0.843 |
| **4.5** | **0.813** | 0.819 | 0.819 | 0.818 | 0.818 | 0.817 | 0.817 | 0.816 | 0.816 | 0.815 | 0.815 | 0.814 | 0.813 | 0.813 |
| **5.0** | **0.792** | 0.798 | 0.798 | 0.797 | 0.797 | 0.796 | 0.796 | 0.795 | 0.795 | 0.794 | 0.793 | 0.793 | 0.792 | 0.791 |
| **5.5** | **0.766** | 0.774 | 0.773 | 0.773 | 0.772 | 0.771 | 0.771 | 0.770 | 0.769 | 0.768 | 0.768 | 0.767 | 0.766 | 0.765 |
| **6.0** | **0.732** | 0.741 | 0.740 | 0.739 | 0.739 | 0.738 | 0.737 | 0.736 | 0.735 | 0.734 | 0.734 | 0.733 | 0.731 | 0.730 |
| **6.5** | **0.692** | 0.703 | 0.702 | 0.701 | 0.700 | 0.699 | 0.698 | 0.697 | 0.696 | 0.695 | 0.694 | 0.693 | 0.691 | 0.690 |
| **7.0** | **0.645** | 0.656 | 0.655 | 0.654 | 0.653 | 0.652 | 0.651 | 0.650 | 0.649 | 0.648 | 0.647 | 0.646 | 0.643 | 0.642 |
| **7.5** | **0.594** | 0.605 | 0.604 | 0.603 | 0.602 | 0.601 | 0.600 | 0.599 | 0.598 | 0.597 | 0.596 | 0.595 | 0.593 | 0.592 |
| **8.0** | **0.551** | 0.562 | 0.561 | 0.560 | 0.559 | 0.558 | 0.557 | 0.556 | 0.555 | 0.554 | 0.553 | 0.552 | 0.550 | 0.549 |
| **8.5** | **0.520** | 0.531 | 0.530 | 0.529 | 0.528 | 0.527 | 0.526 | 0.525 | 0.524 | 0.523 | 0.522 | 0.521 | 0.519 | 0.518 |
| **9.0** | **0.497** | 0.507 | 0.506 | 0.505 | 0.504 | 0.504 | 0.503 | 0.502 | 0.501 | 0.500 | 0.499 | 0.498 | 0.495 | 0.493 |
| **9.5** | **0.470** | 0.485 | 0.484 | 0.483 | 0.482 | 0.481 | 0.480 | 0.478 | 0.477 | 0.475 | 0.474 | 0.472 | 0.468 | 0.465 |
| **10.0** | **0.441** | 0.469 | 0.468 | 0.466 | 0.464 | 0.463 | 0.460 | 0.458 | 0.455 | 0.453 | 0.449 | 0.445 | 0.436 | 0.431 |
| **10.5** | **0.401** | 0.451 | 0.448 | 0.446 | 0.443 | 0.440 | 0.435 | 0.430 | 0.425 | 0.420 | 0.414 | 0.407 | 0.394 | 0.388 |
| **11.0** | **0.357** | 0.426 | 0.421 | 0.416 | 0.411 | 0.406 | 0.400 | 0.393 | 0.386 | 0.379 | 0.372 | 0.364 | 0.349 | 0.342 |
| **11.5** | **0.314** | 0.396 | 0.389 | 0.382 | 0.375 | 0.367 | 0.360 | 0.352 | 0.344 | 0.336 | 0.328 | 0.321 | 0.307 | 0.300 |
| **12.0** | **0.277** | 0.359 | 0.351 | 0.343 | 0.335 | 0.327 | 0.319 | 0.312 | 0.304 | 0.296 | 0.290 | 0.283 | 0.271 | 0.265 |
| **12.5** | **0.246** | 0.322 | 0.314 | 0.306 | 0.298 | 0.290 | 0.283 | 0.277 | 0.270 | 0.263 | 0.257 | 0.252 | 0.241 | 0.236 |
| **13.0** | **0.220** | 0.288 | 0.281 | 0.274 | 0.266 | 0.259 | 0.253 | 0.247 | 0.241 | 0.235 | 0.230 | 0.225 | 0.216 | 0.211 |
| **13.5** | **0.199** | 0.260 | 0.253 | 0.247 | 0.240 | 0.234 | 0.228 | 0.223 | 0.218 | 0.213 | 0.208 | 0.204 | 0.195 | 0.191 |
| **14.0** | **0.180** | 0.234 | 0.228 | 0.222 | 0.216 | 0.211 | 0.206 | 0.201 | 0.197 | 0.192 | 0.188 | 0.184 | 0.177 | 0.173 |
| **14.5** | **0.163** | 0.211 | 0.206 | 0.201 | 0.195 | 0.190 | 0.186 | 0.182 | 0.178 | 0.174 | 0.170 | 0.167 | 0.160 | 0.157 |
| **15.0** | **0.147** | 0.190 | 0.185 | 0.180 | 0.176 | 0.171 | 0.168 | 0.164 | 0.160 | 0.157 | 0.153 | 0.150 | 0.145 | 0.142 |
| **15.5** | **0.134** | 0.172 | 0.168 | 0.164 | 0.160 | 0.156 | 0.152 | 0.149 | 0.146 | 0.142 | 0.140 | 0.137 | 0.132 | 0.129 |
| **16.0** | **0.122** | 0.156 | 0.153 | 0.149 | 0.145 | 0.142 | 0.139 | 0.136 | 0.133 | 0.130 | 0.127 | 0.125 | 0.120 | 0.118 |
| **16.5** | **0.112** | 0.143 | 0.139 | 0.136 | 0.133 | 0.129 | 0.127 | 0.124 | 0.121 | 0.119 | 0.117 | 0.114 | 0.110 | 0.108 |
| **17.0** | **0.103** | 0.131 | 0.128 | 0.125 | 0.122 | 0.119 | 0.116 | 0.114 | 0.111 | 0.109 | 0.107 | 0.105 | 0.101 | 0.099 |
| **17.5** | **0.095** | 0.120 | 0.117 | 0.115 | 0.112 | 0.109 | 0.107 | 0.105 | 0.102 | 0.100 | 0.098 | 0.097 | 0.093 | 0.091 |
| **18.0** | **0.087** | 0.110 | 0.108 | 0.106 | 0.103 | 0.101 | 0.099 | 0.097 | 0.095 | 0.093 | 0.091 | 0.089 | 0.086 | 0.084 |
| **18.5** | **0.081** | 0.102 | 0.100 | 0.098 | 0.095 | 0.093 | 0.091 | 0.089 | 0.087 | 0.086 | 0.084 | 0.083 | 0.080 | 0.078 |
| **19.0** | **0.075** | 0.094 | 0.092 | 0.090 | 0.088 | 0.086 | 0.084 | 0.082 | 0.081 | 0.079 | 0.078 | 0.076 | 0.074 | 0.072 |
| **19.5** | **0.070** | 0.087 | 0.085 | 0.083 | 0.082 | 0.080 | 0.078 | 0.077 | 0.075 | 0.074 | 0.072 | 0.071 | 0.068 | 0.067 |
| **20.0** | **0.065** | 0.081 | 0.079 | 0.078 | 0.076 | 0.074 | 0.073 | 0.071 | 0.070 | 0.069 | 0.067 | 0.066 | 0.064 | 0.063 |
| **20.5** | **0.061** | 0.076 | 0.074 | 0.073 | 0.071 | 0.069 | 0.068 | 0.067 | 0.065 | 0.064 | 0.063 | 0.062 | 0.060 | 0.059 |
| **21.0** | **0.057** | 0.071 | 0.069 | 0.068 | 0.066 | 0.065 | 0.064 | 0.062 | 0.061 | 0.060 | 0.059 | 0.058 | 0.056 | 0.055 |
| **21.5** | **0.054** | 0.067 | 0.065 | 0.064 | 0.063 | 0.061 | 0.060 | 0.059 | 0.058 | 0.057 | 0.056 | 0.055 | 0.053 | 0.052 |
| **22.0** | **0.051** | 0.063 | 0.061 | 0.060 | 0.059 | 0.058 | 0.056 | 0.055 | 0.054 | 0.053 | 0.052 | 0.052 | 0.050 | 0.049 |
| **22.5** | **0.048** | 0.059 | 0.058 | 0.057 | 0.055 | 0.054 | 0.053 | 0.052 | 0.051 | 0.050 | 0.049 | 0.049 | 0.047 | 0.046 |

*Table 12-12: $C_t$ values, noise mode 3*

### 12.4.3 Noise Curve, Noise Mode 3

| **Sound Power Level at Hub Height, Noise Mode 3 (Blades with optional serrated trailing edge)** | |
|---|---|
| **Conditions for Sound Power Level:** | **Measurement standard IEC 61400-11 ed. 3**<br>**Maximum turbulence at 10 metre height: 16%**<br>**Inflow angle (vertical): 0 ±2°**<br>**Air density: 1.225 kg/m$^3$** |
| **Wind speed at hub height [m/s]** | **Sound Power Level at Hub Height ) [dBA]** |
| **3.0** | 89.4 |
| **4.0** | 89.5 |
| **5.0** | 90.4 |
| **6.0** | 94.2 |
| **7.0** | 97.1 |
| **8.0** | 98.8 |
| **9.0** | 99.5 |
| **10.0** | 100.3 |
| **11.0** | 101.1 |
| **12.0** | 101.8 |
| **13.0** | 102.3 |
| **14.0** | 102.5 |
| **15.0** | 102.5 |
| **16.0** | 102.5 |
| **17.0** | 102.5 |
| **18.0** | 102.5 |
| **19.0** | 102.5 |
| **20.0** | 102.5 |

*Table 12-13: Noise curves, noise mode 3*

## 12.5 Mode 4

### 12.5.1 Power Curves, Noise Mode 4

| Air density [kg/m$^3$] | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Wind speed [m/s]** | **1.225** | **0.95** | **0.975** | **1.0** | **1.025** | **1.05** | **1.075** | **1.1** | **1.125** | **1.15** | **1.175** | **1.2** | **1.25** | **1.275** |
| **3.0** | **30** | 13 | 14 | 16 | 17 | 19 | 20 | 22 | 23 | 25 | 27 | 28 | 32 | 33 |
| **3.5** | **97** | 63 | 66 | 69 | 72 | 75 | 78 | 81 | 84 | 87 | 91 | 94 | 100 | 103 |
| **4.0** | **179** | 128 | 133 | 138 | 142 | 147 | 152 | 156 | 161 | 166 | 170 | 175 | 184 | 189 |
| **4.5** | **278** | 205 | 212 | 219 | 225 | 232 | 239 | 245 | 252 | 259 | 265 | 272 | 285 | 292 |
| **5.0** | **396** | 297 | 306 | 315 | 324 | 333 | 342 | 351 | 360 | 369 | 378 | 387 | 405 | 415 |
| **5.5** | **539** | 407 | 419 | 431 | 443 | 455 | 467 | 479 | 491 | 503 | 515 | 527 | 551 | 563 |
| **6.0** | **711** | 541 | 557 | 572 | 588 | 603 | 619 | 634 | 649 | 665 | 680 | 696 | 726 | 742 |
| **6.5** | **912** | 698 | 717 | 737 | 757 | 776 | 796 | 815 | 835 | 854 | 874 | 893 | 931 | 951 |
| **7.0** | **1132** | 879 | 903 | 927 | 951 | 975 | 998 | 1022 | 1045 | 1068 | 1089 | 1111 | 1149 | 1166 |
| **7.5** | **1274** | 1067 | 1092 | 1117 | 1142 | 1167 | 1184 | 1202 | 1220 | 1238 | 1250 | 1262 | 1282 | 1290 |
| **8.0** | **1318** | 1218 | 1234 | 1250 | 1266 | 1282 | 1288 | 1295 | 1302 | 1308 | 1312 | 1315 | 1320 | 1321 |
| **8.5** | **1325** | 1294 | 1300 | 1305 | 1311 | 1317 | 1318 | 1320 | 1322 | 1324 | 1324 | 1324 | 1325 | 1325 |
| **9.0** | **1325** | 1318 | 1320 | 1321 | 1323 | 1324 | 1324 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 |
| **9.5** | **1325** | 1322 | 1323 | 1323 | 1324 | 1324 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 |
| **10.0** | **1325** | 1324 | 1324 | 1324 | 1324 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 |
| **10.5** | **1325** | 1324 | 1324 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 |
| **11.0** | **1325** | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 |
| **11.5** | **1325** | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 |
| **12.0** | **1325** | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 |
| **12.5** | **1325** | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 |
| **13.0** | **1325** | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 |
| **13.5** | **1325** | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 |
| **14.0** | **1325** | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 |
| **14.5** | **1325** | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 |
| **15.0** | **1325** | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 |
| **15.5** | **1325** | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 |
| **16.0** | **1325** | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 |
| **16.5** | **1325** | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 |
| **17.0** | **1325** | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 |
| **17.5** | **1325** | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 |
| **18.0** | **1325** | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 |
| **18.5** | **1325** | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 |
| **19.0** | **1325** | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 |
| **19.5** | **1325** | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 |
| **20.0** | **1325** | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 |
| **20.5** | **1325** | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 |
| **21.0** | **1325** | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 |
| **21.5** | **1325** | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 |
| **22.0** | **1325** | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 |
| **22.5** | **1325** | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 | 1325 |

*Table 12-14: Power curve, noise mode 4*

### 12.5.2 $C_t$ Values, Noise Mode 4

| Air density kg/m$^3$ | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Wind speed [m/s]** | **1.225** | **0.950** | **0.975** | **1.0** | **1.025** | **1.05** | **1.075** | **1.1** | **1.125** | **1.15** | **1.175** | **1.2** | **1.25** | **1.275** |
| **3.0** | **0.918** | 0.927 | 0.926 | 0.925 | 0.924 | 0.924 | 0.923 | 0.922 | 0.921 | 0.920 | 0.920 | 0.919 | 0.917 | 0.917 |
| **3.5** | **0.886** | 0.893 | 0.892 | 0.892 | 0.891 | 0.890 | 0.890 | 0.889 | 0.888 | 0.888 | 0.887 | 0.887 | 0.885 | 0.885 |
| **4.0** | **0.844** | 0.850 | 0.850 | 0.849 | 0.849 | 0.848 | 0.847 | 0.847 | 0.846 | 0.846 | 0.845 | 0.845 | 0.843 | 0.843 |
| **4.5** | **0.814** | 0.820 | 0.819 | 0.819 | 0.818 | 0.817 | 0.817 | 0.816 | 0.816 | 0.815 | 0.815 | 0.814 | 0.813 | 0.813 |
| **5.0** | **0.801** | 0.807 | 0.807 | 0.806 | 0.806 | 0.805 | 0.805 | 0.804 | 0.804 | 0.803 | 0.802 | 0.802 | 0.801 | 0.800 |
| **5.5** | **0.797** | 0.804 | 0.804 | 0.803 | 0.802 | 0.802 | 0.801 | 0.800 | 0.800 | 0.799 | 0.798 | 0.797 | 0.796 | 0.795 |
| **6.0** | **0.790** | 0.799 | 0.798 | 0.797 | 0.797 | 0.796 | 0.795 | 0.794 | 0.793 | 0.792 | 0.791 | 0.790 | 0.789 | 0.788 |
| **6.5** | **0.782** | 0.793 | 0.792 | 0.791 | 0.790 | 0.789 | 0.788 | 0.787 | 0.786 | 0.785 | 0.784 | 0.783 | 0.781 | 0.780 |
| **7.0** | **0.749** | 0.779 | 0.778 | 0.777 | 0.776 | 0.775 | 0.772 | 0.770 | 0.767 | 0.765 | 0.759 | 0.754 | 0.739 | 0.730 |
| **7.5** | **0.633** | 0.740 | 0.734 | 0.729 | 0.723 | 0.717 | 0.706 | 0.695 | 0.684 | 0.673 | 0.660 | 0.647 | 0.619 | 0.604 |
| **8.0** | **0.496** | 0.650 | 0.638 | 0.625 | 0.612 | 0.600 | 0.584 | 0.569 | 0.553 | 0.537 | 0.524 | 0.510 | 0.484 | 0.471 |
| **8.5** | **0.393** | 0.535 | 0.520 | 0.506 | 0.491 | 0.477 | 0.464 | 0.451 | 0.438 | 0.425 | 0.414 | 0.404 | 0.384 | 0.374 |
| **9.0** | **0.321** | 0.433 | 0.421 | 0.409 | 0.396 | 0.384 | 0.374 | 0.364 | 0.354 | 0.345 | 0.337 | 0.329 | 0.314 | 0.307 |
| **9.5** | **0.268** | 0.356 | 0.346 | 0.337 | 0.327 | 0.317 | 0.310 | 0.302 | 0.295 | 0.287 | 0.281 | 0.274 | 0.263 | 0.257 |
| **10.0** | **0.227** | 0.298 | 0.291 | 0.283 | 0.275 | 0.267 | 0.261 | 0.255 | 0.249 | 0.243 | 0.238 | 0.233 | 0.223 | 0.218 |
| **10.5** | **0.195** | 0.254 | 0.248 | 0.241 | 0.235 | 0.229 | 0.223 | 0.218 | 0.213 | 0.208 | 0.204 | 0.199 | 0.191 | 0.188 |
| **11.0** | **0.169** | 0.219 | 0.213 | 0.208 | 0.203 | 0.197 | 0.193 | 0.189 | 0.184 | 0.180 | 0.176 | 0.173 | 0.166 | 0.163 |
| **11.5** | **0.148** | 0.190 | 0.186 | 0.181 | 0.177 | 0.172 | 0.168 | 0.165 | 0.161 | 0.157 | 0.154 | 0.151 | 0.145 | 0.142 |
| **12.0** | **0.130** | 0.167 | 0.163 | 0.159 | 0.155 | 0.151 | 0.148 | 0.145 | 0.141 | 0.138 | 0.136 | 0.133 | 0.128 | 0.125 |
| **12.5** | **0.115** | 0.147 | 0.144 | 0.141 | 0.137 | 0.134 | 0.131 | 0.128 | 0.125 | 0.123 | 0.120 | 0.118 | 0.113 | 0.111 |
| **13.0** | **0.103** | 0.131 | 0.128 | 0.125 | 0.122 | 0.119 | 0.117 | 0.114 | 0.112 | 0.109 | 0.107 | 0.105 | 0.101 | 0.099 |
| **13.5** | **0.093** | 0.118 | 0.115 | 0.112 | 0.110 | 0.107 | 0.105 | 0.103 | 0.101 | 0.098 | 0.096 | 0.095 | 0.091 | 0.090 |
| **14.0** | **0.084** | 0.106 | 0.103 | 0.101 | 0.099 | 0.096 | 0.094 | 0.092 | 0.091 | 0.089 | 0.087 | 0.085 | 0.082 | 0.081 |
| **14.5** | **0.076** | 0.096 | 0.093 | 0.091 | 0.089 | 0.087 | 0.085 | 0.084 | 0.082 | 0.080 | 0.079 | 0.077 | 0.074 | 0.073 |
| **15.0** | **0.069** | 0.086 | 0.084 | 0.083 | 0.081 | 0.079 | 0.077 | 0.076 | 0.074 | 0.073 | 0.071 | 0.070 | 0.067 | 0.066 |
| **15.5** | **0.063** | 0.079 | 0.077 | 0.075 | 0.073 | 0.072 | 0.070 | 0.069 | 0.068 | 0.066 | 0.065 | 0.064 | 0.062 | 0.061 |
| **16.0** | **0.057** | 0.072 | 0.070 | 0.069 | 0.067 | 0.066 | 0.064 | 0.063 | 0.062 | 0.061 | 0.060 | 0.059 | 0.057 | 0.056 |
| **16.5** | **0.053** | 0.066 | 0.064 | 0.063 | 0.062 | 0.060 | 0.059 | 0.058 | 0.057 | 0.056 | 0.055 | 0.054 | 0.052 | 0.051 |
| **17.0** | **0.049** | 0.061 | 0.059 | 0.058 | 0.057 | 0.056 | 0.055 | 0.053 | 0.052 | 0.051 | 0.051 | 0.050 | 0.048 | 0.047 |
| **17.5** | **0.045** | 0.056 | 0.055 | 0.054 | 0.052 | 0.051 | 0.050 | 0.049 | 0.048 | 0.048 | 0.047 | 0.046 | 0.044 | 0.044 |
| **18.0** | **0.042** | 0.052 | 0.051 | 0.050 | 0.049 | 0.048 | 0.047 | 0.046 | 0.045 | 0.044 | 0.043 | 0.043 | 0.041 | 0.041 |
| **18.5** | **0.039** | 0.048 | 0.047 | 0.046 | 0.045 | 0.044 | 0.043 | 0.043 | 0.042 | 0.041 | 0.040 | 0.040 | 0.038 | 0.038 |
| **19.0** | **0.036** | 0.045 | 0.044 | 0.043 | 0.042 | 0.041 | 0.040 | 0.040 | 0.039 | 0.038 | 0.037 | 0.037 | 0.036 | 0.035 |
| **19.5** | **0.034** | 0.042 | 0.041 | 0.040 | 0.039 | 0.038 | 0.038 | 0.037 | 0.036 | 0.036 | 0.035 | 0.034 | 0.033 | 0.033 |
| **20.0** | **0.032** | 0.039 | 0.038 | 0.037 | 0.037 | 0.036 | 0.035 | 0.035 | 0.034 | 0.033 | 0.033 | 0.032 | 0.031 | 0.031 |
| **20.5** | **0.030** | 0.036 | 0.036 | 0.035 | 0.034 | 0.034 | 0.033 | 0.032 | 0.032 | 0.031 | 0.031 | 0.030 | 0.029 | 0.029 |
| **21.0** | **0.028** | 0.034 | 0.034 | 0.033 | 0.032 | 0.032 | 0.031 | 0.031 | 0.030 | 0.029 | 0.029 | 0.029 | 0.028 | 0.027 |
| **21.5** | **0.027** | 0.032 | 0.032 | 0.031 | 0.031 | 0.030 | 0.029 | 0.029 | 0.028 | 0.028 | 0.028 | 0.027 | 0.026 | 0.026 |
| **22.0** | **0.025** | 0.031 | 0.030 | 0.029 | 0.029 | 0.028 | 0.028 | 0.027 | 0.027 | 0.026 | 0.026 | 0.026 | 0.025 | 0.025 |
| **22.5** | **0.024** | 0.029 | 0.028 | 0.028 | 0.027 | 0.027 | 0.026 | 0.026 | 0.025 | 0.025 | 0.025 | 0.024 | 0.024 | 0.023 |

*Table 12-15: $C_t$ values, noise mode 4*

### 12.5.3 Noise Curve, Noise Mode 4

| **Sound Power Level at Hub Height, Noise Mode 4 (Blades with optional serrated trailing edge)** | |
|---|---|
| **Conditions for Sound Power Level:** | **Measurement standard IEC 61400-11 ed. 3**<br>**Maximum turbulence at 10 metre height: 16%**<br>**Inflow angle (vertical): 0 ±2°**<br>**Air density: 1.225 kg/m$^3$** |
| **Wind speed at hub height [m/s]** | **Sound Power Level at Hub Height ) [dBA]** |
| **3.0** | 89.4 |
| **4.0** | 89.5 |
| **5.0** | 90.4 |
| **6.0** | 94.2 |
| **7.0** | 96.1 |
| **8.0** | 97.3 |
| **9.0** | 98.0 |
| **10.0** | 98.8 |
| **11.0** | 99.6 |
| **12.0** | 100.3 |
| **13.0** | 100.8 |
| **14.0** | 101.0 |
| **15.0** | 101.0 |
| **16.0** | 101.0 |
| **17.0** | 101.0 |
| **18.0** | 101.0 |
| **19.0** | 101.0 |
| **20.0** | 101.0 |

*Table 12-16: Noise curves, noise mode 4*

# V126-3.3/3.45 MW™ IEC IIIA/IEC S

## Facts & figures

**POWER REGULATION** — Pitch regulated with variable speed

**OPERATING DATA**

| | |
|---|---|
| Rated power | 3,300 kW |
| Cut-in wind speed | 3 m/s |
| Cut-out wind speed | 22.5 m/s |
| Re cut-in wind speed | 20 m/s |
| Wind class | IEC IIIA;DIBt2/IEC S |

Standard operating temperature range from -20°C* to +45°C with de-rating above 30°C (20°C for 3.45 MW variant)

*subject to different temperature options

**SOUND POWER**
(Noise modes dependent on site and country)

**ROTOR**

| | |
|---|---|
| Rotor diameter | 126 m |
| Swept area | 12,469 m² |
| Air brake | full blade feathering with 3 pitch cylinders |

**ELECTRICAL**

| | |
|---|---|
| Frequency | 50/60 Hz |
| Converter | full scale |

**GEARBOX**

| | |
|---|---|
| Type | two planetary stages and one helical stage |

**TOWER**

| | |
|---|---|
| Hub heights | 117 m (IEC IIIB), 137 m LDST (IEC IIIA/DIBt2), 147 m (IEC IIIA/DIBt2) and 149 m (DIBtS) |

**NACELLE DIMENSIONS**

| | |
|---|---|
| Height for transport | 3.4 m |
| Height installed (incl. CoolerTop®) | 6.8 m |
| Length | 12.8 m |
| Width | 4.0 m |

**HUB DIMENSIONS**

| | |
|---|---|
| Max. transport height | 3.74 m |
| Max. transport width | 3.75 m |
| Max. transport length | 5.42 m |

**BLADE DIMENSIONS**

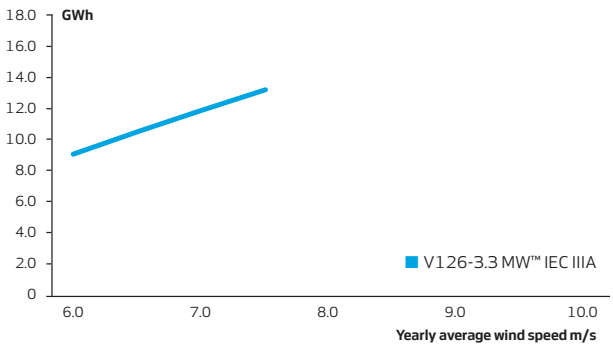
| | |
|---|---|
| Length | 61.7 m |
| Max. chord | 4 m |

| | |
|---|---|
| Max. weight per unit for transportation | 70 metric tonnes |

**TURBINE OPTIONS**

- Condition Monitoring System
- Service Personnel Lift
- Vestas Ice Detection
- Vestas De-Icing
- Low Temperature Operation to - 30°C
- Fire Suppression
- Shadow detection
- Increased Cut-In
- Nacelle Hatch for Air Inlet
- Aviation Lights
- Aviation Markings on the Blades
- Obstacle Collision Avoidance System (OCAS™)

**ANNUAL ENERGY PRODUCTION**




**Assumptions**
One wind turbine, 100% availability, 0% losses, k factor =2, Standard air density = 1.225, wind speed at hub height

## POWER CURVE FOR V126-3.3/3.45 MW™ IEC IIIA/IEC S

Noise reduced sound power modes are available