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PROGETTO PER LA REALIZZAZIONE DI UN IMPIANTO PER LA  
PRODUZIONE DI ENERGIA MEDIANTE LO SFRUTTAMENTO DEL VENTO  
NEL TERRITORIO COMUNALE DI FOGGIA (FG)  
POTENZA NOMINALE 73,2 MW

**PROGETTO DEFINITIVO - SIA**

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# General Description

## 4MW Platform



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## 1 Introduction

The 4MW Platform wind turbine configurations covered by this General Description are listed below with designations according to IEC61400-22.

DIBt 2012 wind classes are also listed where applicable.

Please refer to the Performance Specification for the relevant turbine variant for full wind class definition.

This General Description contains data and descriptions common among the platform variants.

The variant specific performance can be found in the Performance Specifications for the turbine variant and operational mode required.

Turbine Type Class	Turbine Type   Operating Mode
<b>V117-4.0/4.2 MW Strong Wind</b>	V117-4.0 MW IEC IB / IEC IIA 50/60 Hz   Mode 0
	V117-4.0 MW IEC IB / IEC IIA 50/60 Hz   Reactive Power Optimized Mode (QO1)
	V117-4.2 MW IEC S / IEC IIA 50/60 Hz   Power Optimized Mode (PO1)
	V117-3.8 MW IEC IB / IEC IIA 50/60 Hz   Load Optimized Mode (LO1)
	V117-3.6 MW IEC IB / IEC IIA+ 50/60 Hz   Load Optimized Mode (LO2)
<b>V117-4.0/4.2 MW Typhoon</b>	V117-4.0 MW IEC IB-T / IEC IIA-T 50/60 Hz   Mode 0
	V117-4.0 MW IEC IB-T / IEC IIA-T 50/60 Hz   Reactive Power Optim. Mode (QO1)
	V117-4.2 MW IEC S-T / IEC IIA-T 50/60 Hz   Power Optimized Mode (PO1)
	V117-3.8 MW IEC IB-T / IEC IIA-T 50/60 Hz   Load Optimized Mode (LO1)
	V117-3.6 MW IEC IB-T / IEC IIA+-T 50/60 Hz   Load Optimized Mode (LO2)
<b>V136-4.0/4.2 MW</b>	V136-4.0 MW IEC IIB / IEC IIIB 50/60 Hz   Mode 0
	V136-4.0 MW IEC IIB / IEC IIIB 50/60 Hz   Reactive Power Optim. Mode (QO1)
	V136-4.2 MW IEC S / IEC IIIB 50/60 Hz   Power Optimized Mode (PO1)
	V136-3.8 MW IEC IIB / IEC IIIB 50/60 Hz   Load Optimized Mode (LO1)
	V136-3.6 MW IEC IIB / IEC IIIB 50/60 Hz   Load Optimized Mode (LO2)
	V136-4.0 MW DIBt S 50 Hz   Mode 0
	V136-4.0 MW DIBt S 50 Hz   Reactive Power Optimized Mode (QO1)
	V136-4.2 MW DIBt S 50 Hz   Power Optimized Mode (PO1)
	V136-3.8 MW DIBt S 50 Hz   Load Optimized Mode (LO1)
	V136-3.6 MW DIBt S 50 Hz   Load Optimized Mode (LO2)
<b>V150-4.0/4.2 MW</b>	V150-4.0 MW IEC IIIB 50/60 Hz   Mode 0
	V150-4.0 MW IEC IIIB 50/60 Hz   Reactive Power Optim. Mode (QO1)
	V150-4.2 MW IEC S 50/60 Hz   Power Optimized Mode (PO1)
	V150-3.8 MW IEC IIIB / IEC S 50/60 Hz   Load Optimized Mode (LO1)
	V150-3.6 MW IEC IIIB / S 50/60 Hz   Load Optimized Mode (LO2)
	V150-4.0 MW DIBt S 50 Hz   Mode 0



Turbine Type Class	Turbine Type   Operating Mode
<b>V150-4.0/4.2 MW (cont'd)</b>	V150-4.0 MW DIBt S 50 Hz   Reactive Power Optimized Mode (QO1)
	V150-4.2 MW DIBt S 50 Hz   Power Optimized Mode (PO1)
	V150-3.8 MW DIBt S 50 Hz   Load Optimized Mode (LO1)
	V150-3.6 MW DIBt S 50 Hz   Load Optimized Mode (LO2)

*Table 1-1: 4MW Platform turbine configurations covered.*

## 2 General Description

Vestas 4MW Platform comprises a family of wind turbines sharing a common design basis.

The 4MW Platform family of wind turbines includes V105-3.45/3.6 MW, V112-3.45/3.6 MW, V117-3.45/3.6 MW, V126-3.45 MW LTq, V126-3.45/3.6 MW HTq, V136-3.45/3.6 MW, V117-4.0/4.2 MW Strong Wind, V117-4.0/4.2 MW Typhoon, V136-4.0/4.2 MW and V150-4.0/4.2 MW.

For V105-3.45/3.6 MW, V112-3.45/3.6 MW, V117-3.45/3.6 MW, V126-3.45 MW LTq, V126-3.45/3.6 MW HTq and V136-3.45/3.6 MW, please refer to General Description 0053-3707.

This General Description only applies to V117-4.0/4.2 MW Strong Wind, V117-4.0/4.2 MW Typhoon, V136-4.0/4.2 MW and V150-4.0/4.2 MW.

These turbines are pitch regulated upwind turbines with active yaw and a three-blade rotor.

The turbines covered in this General Description are equipped with rotor with diameters residing in the range 117 m to 150 m and a rated output power of 4.0 MW.

A 4.0 MW Reactive Power Optimized Mode (QO1) is available for all variants.

A 4.2 MW Power Optimized Mode (PO1) is available for all variants.

Also, a 3.8 MW Load Optimized Mode (LO1) and a 3.6 MW Load Optimized Mode (LO2) is available for all variants.

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

Operating the wind turbine in 4.0 MW Reactive Power Optimized Mode (QO1) is achieved by applying an extended ambient temperature derate strategy compared with 4.0 MW Mode 0 operation.



Operating the wind turbine in 4.2 MW Power Optimized Mode (PO1) is achieved by applying an extended ambient temperature derate strategy and reduced reactive power capability compared with 4.0 MW Mode 0 operation.

### 3 Mechanical Design

#### 3.1 Rotor

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

Rotor	V117	V136	V150
Diameter	117 m	136 m	150 m
Swept Area	10751 m <sup>2</sup>	14527 m <sup>2</sup>	17671 m <sup>2</sup>
Speed, Dynamic Operation Range	6.7-17.5	5.6-14.0	4.9-12.0
Rotational Direction	Clockwise (front view)		
Orientation	Upwind		
Tilt	6°		
Hub Coning	4°	4°	5.5°
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 bonded to a supporting beam or with embedded structure.

Blades	V117	V136	V150
Type Description	Airfoil shells bonded to supporting beam	Prepreg or infused structural airfoil shell	Prepreg or infused structural airfoil shell
Blade Length	57.15 m	66.66 m	73.66 m
Material	Fibreglass reinforced epoxy, carbon fibres and Solid Metal Tip (SMT)		
Blade Connection	Steel roots inserted		
Airfoils	High-lift profile		
Maximum Chord	4.0 m	4.1 m	4.2 m
Chord at 90% blade radius	1.1 m	1.2 m	1.4 m



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 (V117/V136)	Double-row four-point contact ball bearings
Blade bearing type (V150)	3-rows roller bearings
Lubrication	Manual grease lubrication

Table 3-3: *Blade bearing data*

### 3.4 Pitch System

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

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

Pitch System	
Type	Hydraulic
Number	1 per blade
Range	-10° to 95°

Table 3-4: *Pitch system data*

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

Table 3-5: *Hydraulic system data.*

### 3.5 Hub

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

Hub	
Type	Cast ball shell hub
Material	Cast iron

Table 3-6: Hub data

### 3.6 Main Shaft

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

Main Shaft	
Type Description	Hollow shaft
Material	Cast iron or forged steel

Table 3-7: Main shaft data

### 3.7 Main Bearing Housing

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

Main Bearing Housing	
Material	Cast iron

Table 3-8: Main bearing housing data

### 3.8 Main Bearing

The main bearing carries all thrust loads.

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

Table 3-9: Main bearing data

### 3.9 Gearbox

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

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

Gearbox	
Type	Planetary stages + one helical stage
Gear House Material	Cast
Lubrication System	Pressure oil lubrication
Backup Lubrication System	Oil sump filled from external gravity tank
Total Gear Oil Volume	1000-1500
Oil Cleanliness Codes	ISO 4406-/15/12
Shaft Seals	Labyrinth

Table 3-10: Gearbox data

### 3.10 Generator Bearings

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

### 3.11 High-Speed Shaft Coupling

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

The coupling consists of two 4-link laminate packages and a fibreglass intermediate tube with two metal flanges.

The coupling is fitted to two-armed hubs on the brake disc and the generator hub.

### 3.12 Yaw System

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

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

Table 3-11: Yaw system data

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

Table 3-12: Yaw gear data

### 3.13 Crane

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

Crane	
Lifting Capacity	Maximum 800 kg

Table 3-13: Crane data

### 3.14 Towers

Tubular towers with flange connections, certified according to relevant type approvals, are available in different standard heights. The towers are designed with the majority of internal welded connections replaced by magnet supports to create a predominantly smooth-walled tower.



Magnets provide load support in a horizontal direction and internals, such as platforms, ladders, etc., are supported vertically (that is, in the gravitational direction) by a mechanical connection. The smooth tower design reduces the required steel thickness, rendering the tower lighter compared to one with all internals welded to the tower shells.

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

<b>Towers</b>	
<b>Type</b>	Cylindrical/conical tubular

*Table 3-14: Tower structure data*

### **3.15 Nacelle Bedplate and Cover**

The nacelle cover is made of fibreglass. Hatches are positioned in the floor for lowering or hoisting equipment to the nacelle and evacuation of personnel. The roof section is equipped with wind sensor system and 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 yaw system.

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

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

Type Description	Material
<b>Nacelle Cover</b>	GRP
<b>Bedplate Front</b>	Cast iron
<b>Bedplate Rear</b>	Girder structure

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

### **3.16 Thermal Conditioning System**

The thermal conditioning system consists of a few robust components:

- The Vestas CoolerTop<sup>®</sup> located on top of the rear end of the nacelle. The CoolerTop<sup>®</sup> is a free flow cooler, thus ensuring that there are no electrical components in the thermal conditioning system located outside the nacelle.



- The CoolerTop is available in a standard variant and an optional high temperature variant with improved cooler performance at high ambient temperatures (HT version is not available for all turbine variants. Please consult Vestas for more information).
- The CoolerTop® comes as standard in a “naked” form, with no side cover panels. Side cover panels are available as an option.
- The Liquid Cooling System, which serves the gearbox, hydraulic systems, generator and converter is driven by an electrical pumping system.
- The transformer forced air cooling comprised of an electrical fan.

### 3.16.1 Generator and Converter Cooling

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

### 3.16.2 Gearbox and Hydraulic Cooling

The gearbox and hydraulic cooling systems are coupled in parallel. A dynamic flow valve mounted in the gearbox cooling circuit divides the cooling flow. The cooling liquid removes heat from the gearbox and the hydraulic power unit through heat exchangers and a free-air flow radiator placed on the top of the nacelle.

In addition to the heat exchangers and the radiator, the circulation system includes an electrical pump and a three-way thermostatic valve.

### 3.16.3 Transformer Cooling

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

### 3.16.4 Nacelle Cooling

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

### 3.16.5 Optional Air Intake Hatches

Specific 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.

## 4 Electrical Design

### 4.1 Generator

The generator is a three-phase asynchronous induction generator with cage rotor that is connected to the grid through a full-scale converter. The generator housing allows the circulation of cooling air within the stator and rotor.



The air-to-water heat exchange occurs in an external heat exchanger.

Generator	
<b>Type</b>	Asynchronous with cage rotor
<b>Rated Power [P<sub>N</sub>]</b>	4250 / 4450 kW
<b>Frequency [f<sub>N</sub>]</b>	0-100 Hz
<b>Voltage, Stator [U<sub>NS</sub>]</b>	3 x 800 V (at rated speed)
<b>Number of Poles</b>	6
<b>Winding Type</b>	Form with VPI (Vacuum Pressurized Impregnation)
<b>Winding Connection</b>	Delta
<b>Rated rpm</b>	1450-1550 rpm
<b>Overspeed Limit Acc. to IEC (2 minutes)</b>	2400 rpm
<b>Generator Bearing</b>	Hybrid/ceramic
<b>Temperature Sensors, Stator</b>	3 PT100 sensors placed at hot spots and 3 as back-up
<b>Temperature Sensors, Bearings</b>	1 per bearing
<b>Insulation Class</b>	H
<b>Enclosure</b>	IP54

Table 4-1: Generator data

## 4.2 Converter

The converter is a full-scale converter system controlling both the generator and the power quality delivered to the grid. The converter consists of 3 machine-side converter units and 3 line-side converter units operating in parallel with a common controller.

The converter controls conversion of variable frequency 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 up to 800 V dependent on generator speed.

Converter	
<b>Rated Apparent Power [S<sub>N</sub>]</b>	5100 kVA
<b>Rated Grid Voltage</b>	3 x 720 V
<b>Rated Generator Voltage</b>	3 x 800 V
<b>Rated Grid Current</b>	4100 A (≤30°C ambient) / 4150 (≤20°C ambient)
<b>Rated Generator Current</b>	3600 A (≤30°C ambient) / 3650 (≤20°C ambient)
<b>Enclosure</b>	IP54



Table 4-2: Converter data

### 4.3 HV Transformer

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

The transformer is a three-phase, three limb, two-winding, dry-type transformer that is self-extinguishing. The windings are delta-connected on the high-voltage side and star connected on the low voltage side.

The transformer is designed according to IEC standards, but also complying to European Eco-design regulation No 548/2014 and No 2019/1783 set by the European Commission.

The transformer supplied for countries under EU legislation will be:

- Eco-design based on Tier 1 requirements (effective in EU until 1 July 2021)<sup>1</sup>.
- Eco-design based on Tier 2 requirements (effective in EU from 1 July 2021)<sup>1</sup>.

For other countries Eco-design based on Tier 1 requirements will be supplied as default.

#### 4.3.1 Eco-designs - IEC 50 Hz/60 Hz version

Transformer	
Type description	Eco-design dry-type cast resin transformer.
Basic layout	3 phase, 3 limb, 2 winding transformer.
Applied standards	IEC 60076-11, IEC 60076-16, IEC 61936-1, Commission Regulation No 548/2014 and Commission Regulation No 2019/1783.
Cooling method	AF
Rated power	5150 kVA
Rated voltage, turbine side	
U <sub>m</sub> 1.1kV	0.720 kV
Rated voltage, grid side	
U <sub>m</sub> 24.0kV	15.7-22.0 kV
U <sub>m</sub> 36.0kV	22.1-33.0 kV
U <sub>m</sub> 40.5kV	33.1-36.0 kV
Insulation level AC / LI / LIC	
U <sub>m</sub> 1.1kV	3 <sup>2</sup> / 3 / 3 kV
U <sub>m</sub> 24.0kV	50 <sup>2</sup> / 125 / 125 kV
U <sub>m</sub> 36.0kV	70 <sup>2</sup> / 170 / 170 kV
U <sub>m</sub> 40.5kV	80 <sup>2</sup> / 170 / 170 kV
Off-circuit tap changer	±2 x 2.5 %
Frequency	50 Hz / 60 Hz
Vector group	Dyn5
No-load current <sup>3</sup>	~0.5 %
Positive sequence short-circuit impedance @ rated power, reference temperature according to IEC 60076-11 <sup>4</sup>	9.9 %
Positive sequence short-circuit resistance @ rated power, reference temperature according to IEC 60076-11 <sup>3</sup>	~0.8 %

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Transformer	
<b>Zero sequence short-circuit impedance@ rated power, reference temperature according to IEC 60076-11 <sup>3</sup></b>	~8.3 %
<b>Zero sequence short-circuit resistance@ rated power, reference temperature according to IEC 60076-11 <sup>3</sup></b>	~0.7 %
<b>No-load reactive power <sup>3</sup></b>	~20 kVAr
<b>Full load reactive power <sup>3</sup></b>	~550 kVAr
<b>Inrush peak current <sup>3</sup></b>	5-8 x $I_n$ A
<b>Half crest time <sup>3</sup></b>	~ 0.6 s
<b>Sound power level</b>	≤ 80 dB(A)
<b>Average temperature rise at max altitude</b>	≤ 90 K
<b>Max altitude <sup>5</sup></b>	2000 m
<b>Insulation class</b>	
<b>LV coil</b>	155 (F)
<b>HV coil</b>	155 (F) or 180 (H)
<b>Environmental class</b>	E2
<b>Climatic class</b>	C2
<b>Fire behaviour class</b>	F1
<b>Corrosion class</b>	C4
<b>Weight</b>	≤11000 kg
<b>Temperature monitoring</b>	PT100 sensors in LV windings and core
<b>Overvoltage protection</b>	Surge arresters on HV terminals
<b>Temporary earthing</b>	3 x Ø25 mm earthing ball points

*Table 4-3: Transformer data for Eco-designs 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 requirements.

The maximum losses are described by the PEI limit section and stretches over a range between Loss variant 1 and Loss variant 2, see Figure 4-1 and Figure 4-2. 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.





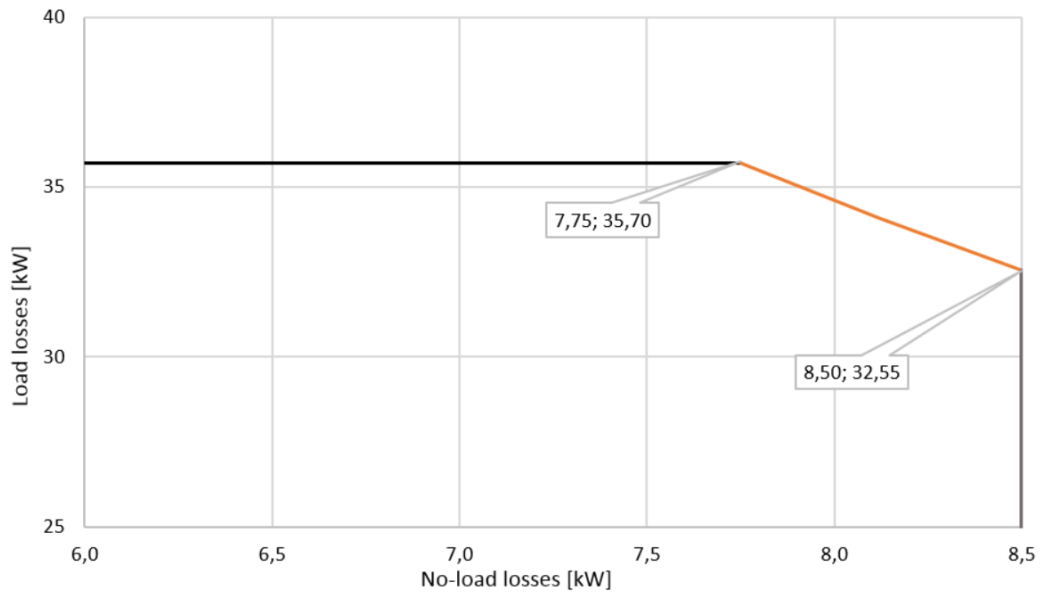


Figure 4-1 Transformer losses allowable area for Tier 1

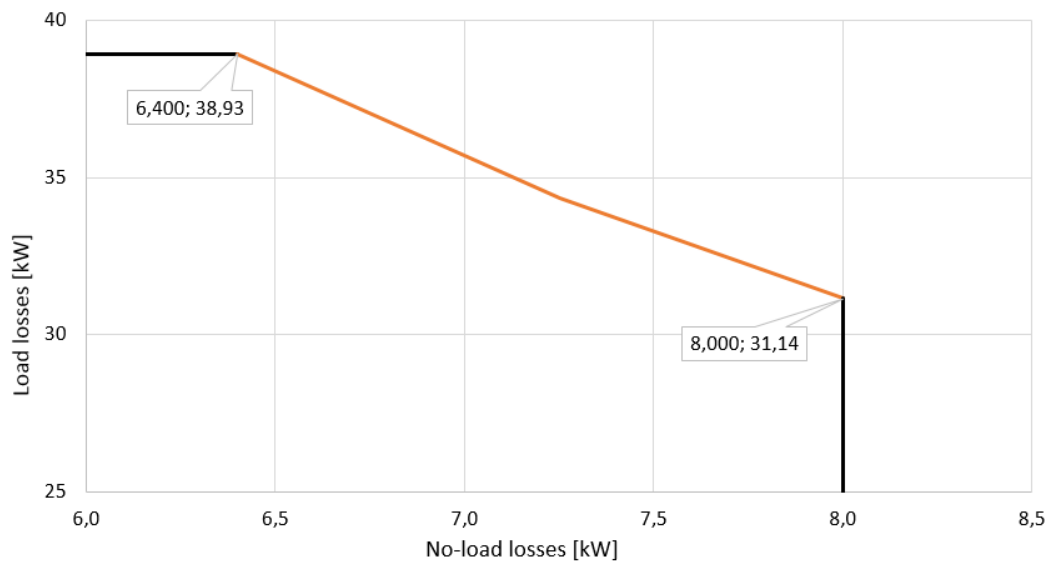


Figure 4-2 Transformer losses allowable area for Tier 2

The actual load losses vary depend on the operation mode of the turbine, hence in Table 4-4 the load losses are provided at different operation modes for the two loss variants. Table 4-4 covers both Tier 1 and Tier 2 transformer design. For further recalculation of load losses at different operation modes, refer to Figure 4-3.



<b>Transformer losses Tier 1</b>			
<b>Peak Efficiency Index (PEI)</b>	> 99.354		
<b>Loss variant 1</b>			
<b>No-load loss</b>	7.75 kW		
<b>Load loss @ power, reference temperature according to IEC 60076-11</b>	<b>@5150kVA</b> ≤ 35.70 kW	<b>@4200kVA<sup>6</sup></b> ≤ 23.75 kW	<b>@4000kVA<sup>6</sup></b> ≤ 21.54 kW
<b>Loss variant 2</b>			
<b>No-load loss</b>	8.5 kW		
<b>Load loss @ power, reference temperature according to IEC 60076-11</b>	<b>@5150kVA</b> ≤ 32.55 kW	<b>@4200kVA<sup>6</sup></b> ≤ 21.65 kW	<b>@4000kVA<sup>6</sup></b> ≤ 19.64 kW
<b>Transformer losses Tier 2</b>			
<b>Peak Efficiency Index (PEI)</b>	> 99.387		
<b>Loss variant 1</b>			
<b>No-load loss</b>	6.4 kW		
<b>Load loss @ power, reference temperature according to IEC 60076-11</b>	<b>@5150kVA</b> ≤ 39.93 kW	<b>@4200kVA<sup>6</sup></b> ≤ 25.89 kW	<b>@4000kVA<sup>6</sup></b> ≤ 23.49 kW
<b>Loss variant 2</b>			
<b>No-load loss</b>	8.0 kW		
<b>Load loss @ power, reference temperature according to IEC 60076-11</b>	<b>@5150kVA</b> ≤ 31.14 kW	<b>@4200kVA<sup>6</sup></b> ≤ 20.71 kW	<b>@4000kVA<sup>6</sup></b> ≤ 18.79 kW

Table 4-4: Transformer losses for Eco-designs IEC 50 Hz/60 Hz version.

- NOTE**
- <sup>1</sup> The date reflects date for shipment of transformer from manufacturer.
  - <sup>2</sup> @1000m. According to IEC 60076-11, AC test voltage is altitude dependent.
  - <sup>3</sup> Based on an average of calculated values across voltages and manufacturers.
  - <sup>4</sup> Subjected to standard IEC tolerances.
  - <sup>5</sup> Transformer max altitude may be adjusted to match turbine location. For voltage class Um 40,5 kV altitude are limited to 1000m for Eco-design Tier 2.
  - <sup>6</sup> Information values based on operation mode, see Figure 4-3.



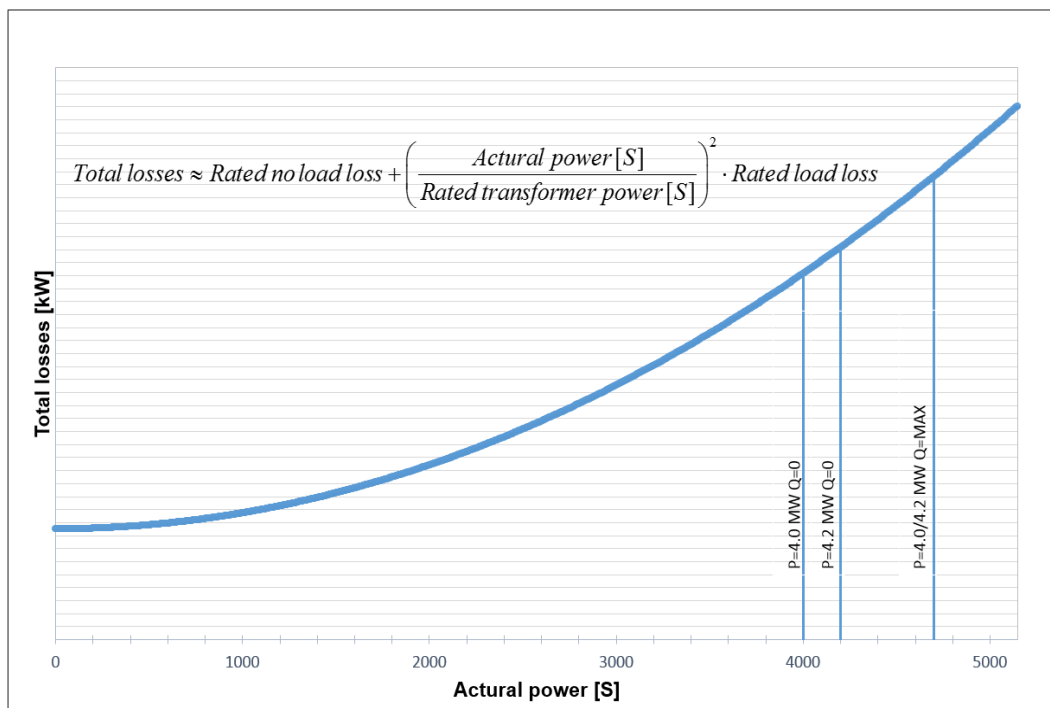


Figure 4-3: Total Losses vs. Actual Power.

#### 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.

<b>HV Cables</b>	
<b>High-Voltage Cable Insulation Compound</b>	Improved ethylene-propylene (EP) based material-EPR or high modulus or hard grade ethylene-propylene rubber-HEPR
<b>Pre-terminated</b>	HV termination in transformer end. T-Connector Type-C in switchgear end.
<b>Maximum Voltage</b>	24 kV for 19.1-22.0 kV rated voltage 42 kV for 22.1-36.0 kV rated voltage
<b>Conductor Cross Sections</b>	3x70 / 70 mm <sup>2</sup> (Single PE core) 3x70 + 3x70/3 mm <sup>2</sup> (Split PE core)

*Table 4-5: 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 4-6. 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 4-7 for the IEC version and in Table 4-8 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	⊙	⊙	⊙
Disconnecter / 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	○	○	⊙
SCADA operation and feedback of circuit breaker	○	○	⊙
SCADA operation and feedback of switch disconnector	○	○	⊙

Table 4-6: HV switchgear variants and features



### 4.5.1 IEC 50/60Hz version

<b>HV Switchgear</b>	
<b>Type description</b>	Gas Insulated Switchgear
<b>Applied standards</b>	IEC 62271-103 IEC 62271-1, 62271-100, 62271-102, 62271-200, IEC 60694
<b>Insulation medium</b>	SF <sub>6</sub>
<b>Rated voltage</b>	
<b>U<sub>r</sub> 24.0kV</b>	15.7-22.0 kV
<b>U<sub>r</sub> 36.0kV</b>	22.1-33.0 kV
<b>U<sub>r</sub> 40.5kV</b>	33.1-36.0 kV
<b>Rated insulation level AC // LI Common value / across isolation distance</b>	
<b>U<sub>r</sub> 24.0kV</b>	50 / 60 // 125 / 145 kV
<b>U<sub>r</sub> 36.0kV</b>	70 / 80 // 170 / 195 kV
<b>U<sub>r</sub> 40.5kV</b>	85 / 90 // 185 / 215 kV
<b>Rated frequency</b>	50 Hz / 60 Hz
<b>Rated normal current</b>	630 A
<b>Rated Short-time withstand current</b>	
<b>U<sub>r</sub> 24.0kV</b>	20 kA
<b>U<sub>r</sub> 36.0kV</b>	25 kA
<b>U<sub>r</sub> 40.5kV</b>	25 kA
<b>Rated peak withstand current 50 / 60 Hz</b>	
<b>U<sub>r</sub> 24.0kV</b>	50 / 52 kA
<b>U<sub>r</sub> 36.0kV</b>	62.5 / 65 kA
<b>U<sub>r</sub> 40.5kV</b>	62.5 / 65 kA
<b>Rated duration of short-circuit</b>	1 s
<b>Internal arc classification (option)</b>	
<b>U<sub>r</sub> 24.0kV</b>	IAC A FLR 20 kA, 1 s
<b>U<sub>r</sub> 36.0kV</b>	IAC A FLR 25 kA, 1 s
<b>U<sub>r</sub> 40.5kV</b>	IAC A FLR 25 kA, 1 s
<b>Connection interface</b>	Outside cone plug-in bushings, IEC interface C1.
<b>Loss of service continuity category</b>	LSC2
<b>Ingress protection</b>	
<b>Gas tank</b>	IP 65
<b>Enclosure</b>	IP 2X
<b>LV cabinet</b>	IP 3X
<b>Corrosion class</b>	C3

Table 4-7: 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 <sub>6</sub>
Rated voltage	
<b>U<sub>r</sub> 38.0kV</b>	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	
<b>Gas tank</b>	NEMA 4X / IP 65
<b>Enclosure</b>	NEMA 2 / IP 2X
<b>LV cabinet</b>	NEMA 2 / IP 3X
Corrosion class	C3

Table 4-8: HV switchgear data for IEEE version

### 4.6 AUX System

The AUX system is supplied from a separate 650/400/230 V transformer located in the nacelle inside the converter cabinet. All motors, pumps, fans and heaters are supplied from this system.

230 V consumers are generally supplied from a 400/230 V transformer located in the tower base. Internal heating and ventilation of cabinets as well as specific option 230 V consumers are supplied from the auxiliary transformer in the converter cabinet.

Power Sockets	
Single Phase (Nacelle)	230 V (16 A) (standard) 110 V (16 A) (option) 2 x 55 V (16 A) (option)
Single Phase (Tower Platforms)	230 V (10 A) (standard) 110 V (16 A) (option) 2 x 55 V (16 A) (option)
Three Phase (Nacelle and Tower Base)	3 x 400 V (16 A)

Table 4-9: AUX system data

## 4.7 Wind Sensing System

The turbine is equipped with a wind sensing system which can provide the wind speed and wind direction in all weather conditions. It consists of at least one wind sensor combined with different estimators which gives an estimate of the wind in the entire rotor area.

## 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<sup>®</sup> - 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.

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.



Backup Time	Standard	Optional
Control System* (230V AC and 24VDC UPS)	30 min	Up to 19.5 hours **
Ready to protect (24V DC UPS)	7 days	80 days***

Table 4-10: UPS data

Light Box		
Backup Time	Standard	Optional
Internal Lights	30 min	60 min****

Table 4-11: 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 24V DC UPS with extra battery panel.

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

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**NOTE** For alternative backup times, consult Vestas.

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## 5 Turbine Protection Systems

### 5.1 Braking Concept

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

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



## 5.2 Short Circuit Protections

Breakers	Breaker for Aux. Power. Back-up CB (T5V-HA 400A TMA 800V) and aux. power CB (T4V-HA 125A TMA 800V) tested in coordination	Breaker 1 for Converter Modules MTZ2 1600A 1000 V	Breaker 2 for Converter Modules MTZ2 3200A 1000 V
Breaking Capacity $I_{cu}$ , $I_{cs}$	75 kA rms @ max 840 V $I_{cs} = 100\%$	66 kA rms @ max 1000 V $I_{cs} = 100\%$	66 kA rms @ max 1000 V $I_{cs} = 100\%$
Making Capacity $I_{cm}$	166 kA peak @ max 840 V	145 kA peak @ max 1000 V	145 kA peak @ max 1000 V

Table 5-1: Short circuit protection data

## 5.3 Overspeed Protection

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

The safety-related partition of the VMP8000 control system monitors the rotor rpm. In case of an overspeed situation, the safety-related partition of the VMP8000 control system activates the emergency feathered position (full feathering) of the three blades independently of the non-safety related partition of VMP8000 control system.

Overspeed Protection	
Sensors Type	Inductive
Trip Level (variant dependent)	12.0-17.5 rpm / 2000 (generator rpm)

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

## 5.6 Lightning Protection of Blades, Nacelle, Hub and Tower

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

- Lightning receptors. 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.

V136 blades and V150 blades:

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

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

Hub/Nacelle/Tower/Foundation and V117 blades:

Lightning Protection Design Parameters			Protection Level I
<b>Current Peak Value</b>	$i_{max}$	[kA]	200
<b>Impulse Charge</b>	$Q_{impulse}$	[C]	200
<b>Long Duration Charge</b>	$Q_{long}$	[C]	600
<b>Total Charge</b>	$Q_{total}$	[C]	800
<b>Specific Energy</b>	W/R	[MJ/Ω]	20
<b>Average Steepness</b>	di/dt	[kA/μs]	200

Table 5-4: Lightning protection design parameters (IEC & JIS)

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

## 5.7 EMC

The turbine and related equipment fulfils 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.

## 5.8 Earthing

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

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

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

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

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

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

## 5.9 Corrosion Protection

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

Corrosion Protection	External Areas	Internal Areas
Nacelle	C5	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 meter above ground level. The door is equipped with a lock. Access to the top platform in the tower is by a ladder or service lift. Access to the nacelle from the top platform is by ladder. Access to the transformer room in the nacelle is controlled with a lock. Unauthorised access to electrical switchboards and power panels in the turbine is prohibited according to IEC 60204-1 2006.

### 6.2 Escape

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



The hatch in the roof can be opened from both the inside and outside. Escape from the service lift is by ladder.

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

### **6.3 Rooms/Working Areas**

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

### **6.4 Floors, Platforms, Standing, and Working Places**

All floors have anti-slip surfaces.

There is one floor per tower section.

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

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

### **6.5 Service Lift**

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

### **6.6 Climbing Facilities**

The tower ladder is equipped with a fall arrest system, either a rail system 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 cylinder can be done with mechanical tools in the hub.

### **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 bottom of the tower.

## 6.10 Power Disconnection

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

## 6.11 Fire Protection/First Aid

A handheld 5-6 kg CO<sub>2</sub> 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<sub>2</sub> fire extinguisher is required only during service and maintenance activities, unless a permanently mounted fire extinguisher located in the nacelle is mandatorily required by authorities.
- First aid kits are required only during service and maintenance activities.
- Fire blankets are required only during non-electrical hot work activities.

## 6.12 Warning Signs

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

## 6.13 Manuals and Warnings

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

## 7 Environment

### 7.1 Chemicals

Chemicals used in the turbine are evaluated according to the Vestas Wind Systems A/S Environmental System certified according to ISO 14001:2015. The following chemicals are used in the turbine:

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

## 8 Design Codes

### 8.1 Design Codes – Structural Design

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

Design Codes	
Nacelle and Hub	IEC 61400-1 Edition 3 EN 50308



Design Codes	
<b>Tower</b>	IEC 61400-1 Edition 3 Eurocode 3
<b>Blades</b>	DNV-OS-J102 IEC 1024-1 IEC 60721-2-4 IEC 61400 (Part 1, 12 and 23) IEC WT 01 IEC DEFU R25 ISO 2813 DS/EN ISO 12944-2
<b>Gearbox</b>	IEC 61400-4
<b>Generator</b>	IEC 60034
<b>Transformer</b>	IEC 60076-11, IEC 60076-16, CENELEC HD637 S1
<b>Lightning Protection</b>	IEC 62305-1: 2006 IEC 62305-3: 2006 IEC 62305-4: 2006 IEC 61400-24:2010 JIS C 1400-24 2014
<b>Rotating Electrical Machines</b>	IEC 34
<b>Safety of Machinery, Safety-related Parts of Control Systems</b>	IEC 13849-1
<b>Safety of Machinery – Electrical Equipment of Machines</b>	IEC 60204-1

Table 8-1: Design codes

## 9 Colours

### 9.1 Nacelle Colour

Colour of Vestas Nacelles	
<b>Standard Nacelle Colour</b>	RAL 7035 (light grey)
<b>Standard Logo</b>	Vestas

Table 9-1: Colour, nacelle





## 9.2 Tower Colour

Colour of Vestas Tower Section		
	External:	Internal:
<b>Standard Tower Colour</b>	RAL 7035 (light grey)	RAL 9001 (cream white)

Table 9-2: Colour, tower

## 9.3 Blade Colour

Blade Colour	
<b>Standard Blade Colour</b>	RAL 7035 (light grey). All lightning receptor surfaces on the blades are unpainted, excluding the Solid Metal Tips (SMT).
<b>Tip-End Colour Variants</b>	RAL 2009 (traffic orange), RAL 3020 (traffic red)
<b>Gloss</b>	< 30% DS/EN ISO 2813

Table 9-3: Colour, blades

## 10 Operational Envelope and Performance Guidelines

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

### 10.1 Climate and Site Conditions

Values refer to hub height:

Extreme Design Parameters	
Wind Climate	All
<b>Ambient Temperature Interval (Standard Temperature Turbine)</b>	-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	
<b>Ambient Temperature Interval (V117 and V136 Standard Turbine)</b>	-20° to +45°C
<b>Ambient Temperature Interval (V117 and V136 Low Temperature Turbine)</b>	-30° to +45°C



Operational Envelope – Temperature	
Ambient Temperature Interval (V150 Standard Turbine)	-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 the low temperature options of the wind turbine, 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.

### 10.3 Operational Envelope – Temperature and Altitude

The turbine comes in two cooler top configurations with different performance as function of temperature. Figure 10-1 illustrate performance for standard cooler top and Figure 10-2 illustrate performance for high temperature cooler top. (HT version is not available for all turbine variants. Please consult Vestas for more information).

The values in the graphs refer to hub height and are determined by the sensors and control system of the turbine. At ambient temperatures above the thresholds shown in the figures the turbine will maintain derated production. The derate values depend of the altitude of the turbine.

The graphs show the derate curve for PO1. Mode 0, LO1 and LO2 will follow the same derate curve, but with a nominal power at respectively 4.0MW, 3.8MW and 3.6MW.



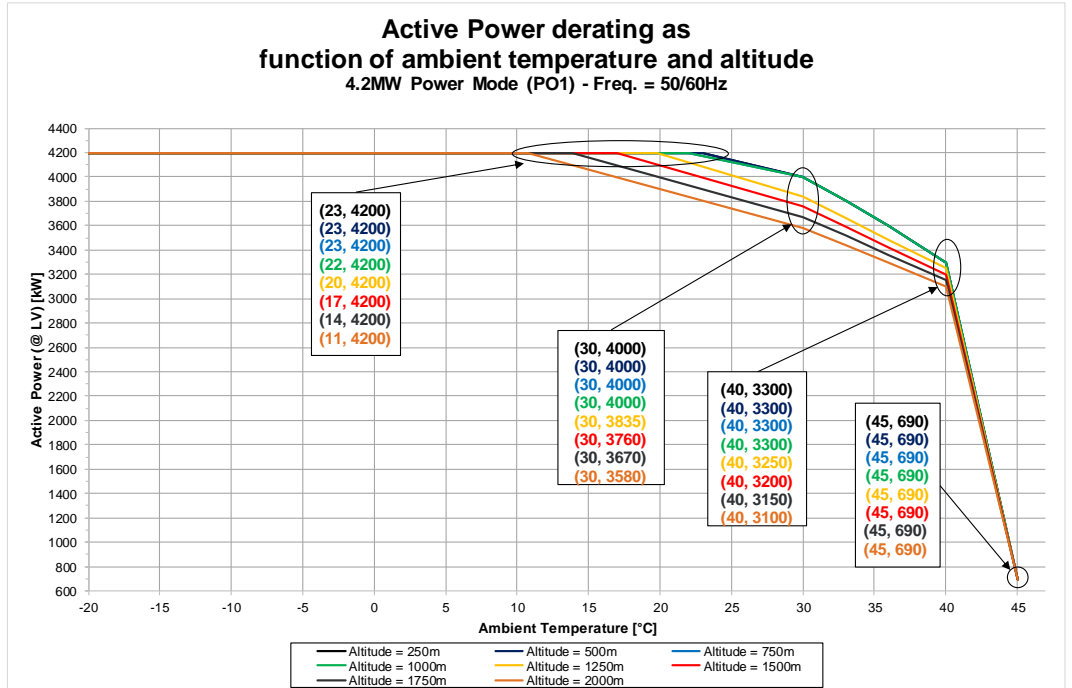


Figure 10-1: Temperature dependant derated operation – Standard Cooler Top.

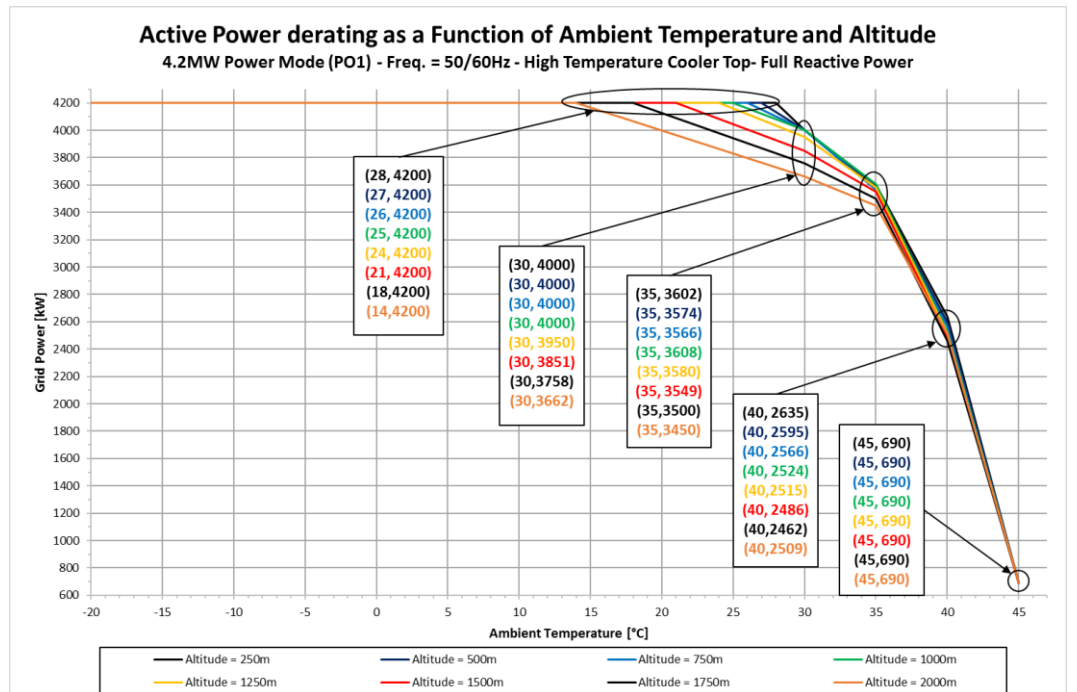


Figure 10-2: Temperature dependant derated operation – High Temperature Cooler Top.

## 10.4 Operational Envelope – Grid Connection

Operational Envelope – Grid Connection		
<b>Nominal Phase Voltage</b>	[U <sub>NP</sub> ]	720 V
<b>Nominal Frequency</b>	[f <sub>N</sub> ]	50/60 Hz
<b>Maximum Frequency Gradient</b>	±4 Hz/sec.	
<b>Maximum Negative Sequence Voltage</b>	3% (connection) 2% (operation)	
<b>Minimum Required Short Circuit Ratio at Turbine HV Connection</b>	5.0 (contact Vestas for lower SCR levels)	
<b>Maximum Short Circuit Current Contribution</b>	Contact Vestas for details	

Table 10-3: Operational envelope – grid connection

The generator and the converter will be disconnected if\*:

Protection Settings	
<b>Voltage Above 110%** of Nominal for 1800 Seconds</b>	792 V
<b>Voltage Above 116% of Nominal for 60 Seconds</b>	835 V
<b>Voltage Above 125% of Nominal for 2 Seconds</b>	900 V
<b>Voltage Above 136% of Nominal for 0.150 Seconds</b>	979 V
<b>Voltage Below 90%** of Nominal for 180 Seconds (FRT)</b>	648 V
<b>Voltage Below 85% of Nominal for 12 Seconds (FRT)</b>	612 V
<b>Voltage Below 80% of Nominal for 4.8 Seconds (FRT)</b>	576 V
<b>Frequency is Above 106% of Nominal for 0.2 Seconds</b>	53/63.6 Hz
<b>Frequency is Below 94% of Nominal for 0.2 Seconds</b>	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.

### 10.5 Operational Envelope – Reactive Power Capability in 4.0 MW Mode 0

The turbine has a reactive power capability in 4.0 MW Mode 0 on the low voltage side of the HV transformer as illustrated in Figure 10-3:

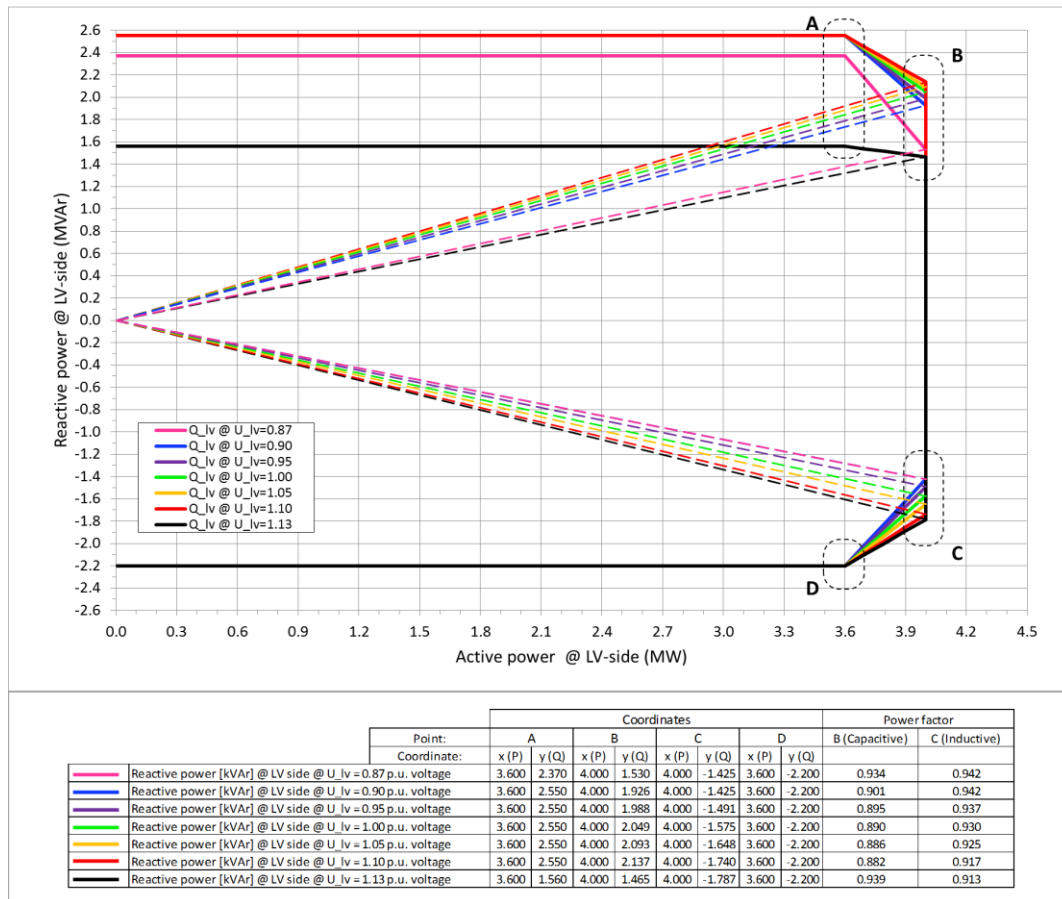


Figure 10-3: Reactive power capability for 4.0 MW Mode 0.

When operating at 4.0 MW nominal power at LV side of the HV transformer, the reactive power capability on the high voltage side of the HV transformer is approximately:

- $\cos\phi(HV) = 0.95/0.90$  capacitive/inductive @  $U(HV) = 0.90$  p.u. voltage
- $\cos\phi(HV) = 0.93/0.87$  capacitive/inductive @  $U(HV) = 1.10$  p.u. 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.



### 10.6 Operational Envelope – Reactive Power Capability in 4.0 MW Reactive Power Optimized Mode (QO1)

An optional, extended reactive power capability is available with 4.0 MW Reactive Power Optimized Mode (QO1) when ambient temperature is below +20°C for ≤1000 m.a.s.l. The reactive power capability is as seen in Figure 10-4:

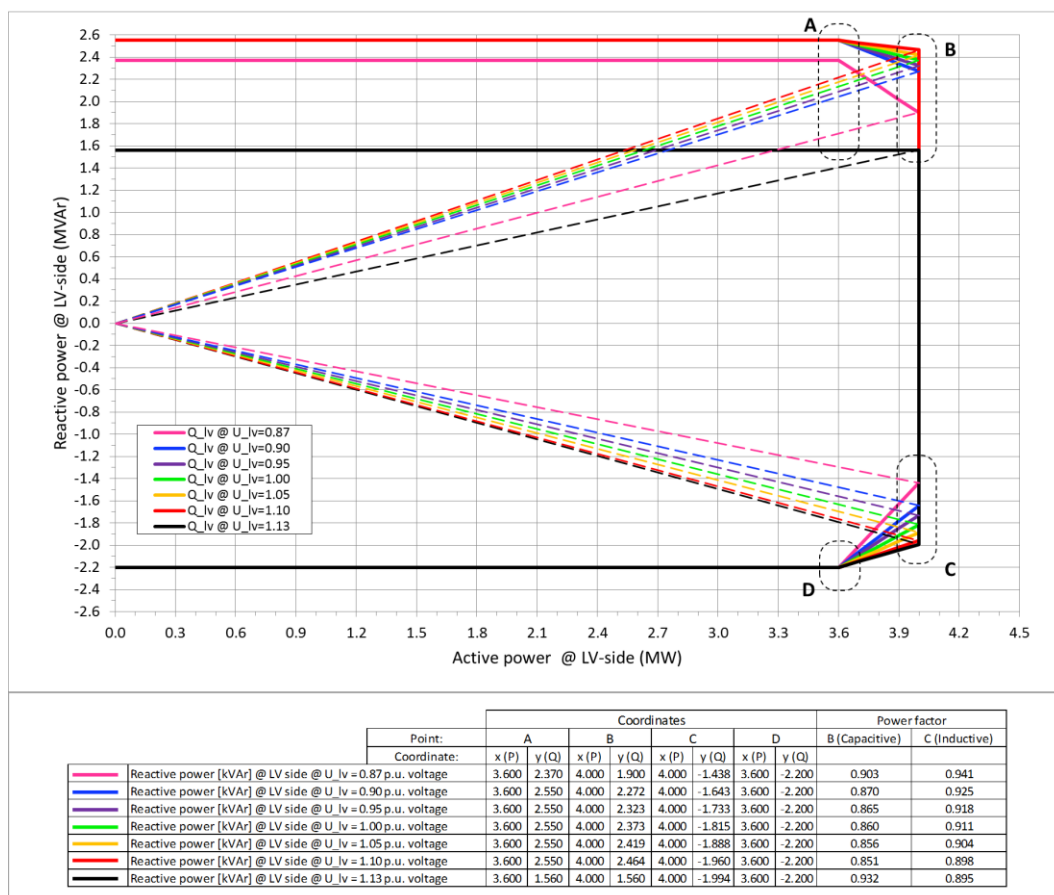


Figure 10-4: Reactive power capability for 4.0 MW Reactive Power Optimized Mode (QO1).

When operating at 4.0 MW in Reactive Power Optimized Mode (QO1) at LV side of the HV transformer, the reactive power capability on the high voltage side of the HV transformer is approximately:

- $\cos\phi(\text{HV}) = 0.92/0.88$  capacitive/inductive @  $U(\text{HV}) = 0.90$  p.u. voltage
- $\cos\phi(\text{HV}) = 0.90/0.85$  capacitive/inductive @  $U(\text{HV}) = 1.10$  p.u. voltage

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

**NOTE**

4.0 MW Reactive Power Optimized Mode (QO1) derates reactive power linearly above +20°C ambient temperature to converge with the reactive power capability of 4.0 MW Mode 0 in Figure 10-3 at +30°C.



### 10.7 Operational Envelope – Reactive Power Capability in 4.2 MW Power Optimized Mode (PO1)

The reactive power capability for the 4.2 MW Power Optimized Mode (PO1) is as illustrated in Figure 10-5:

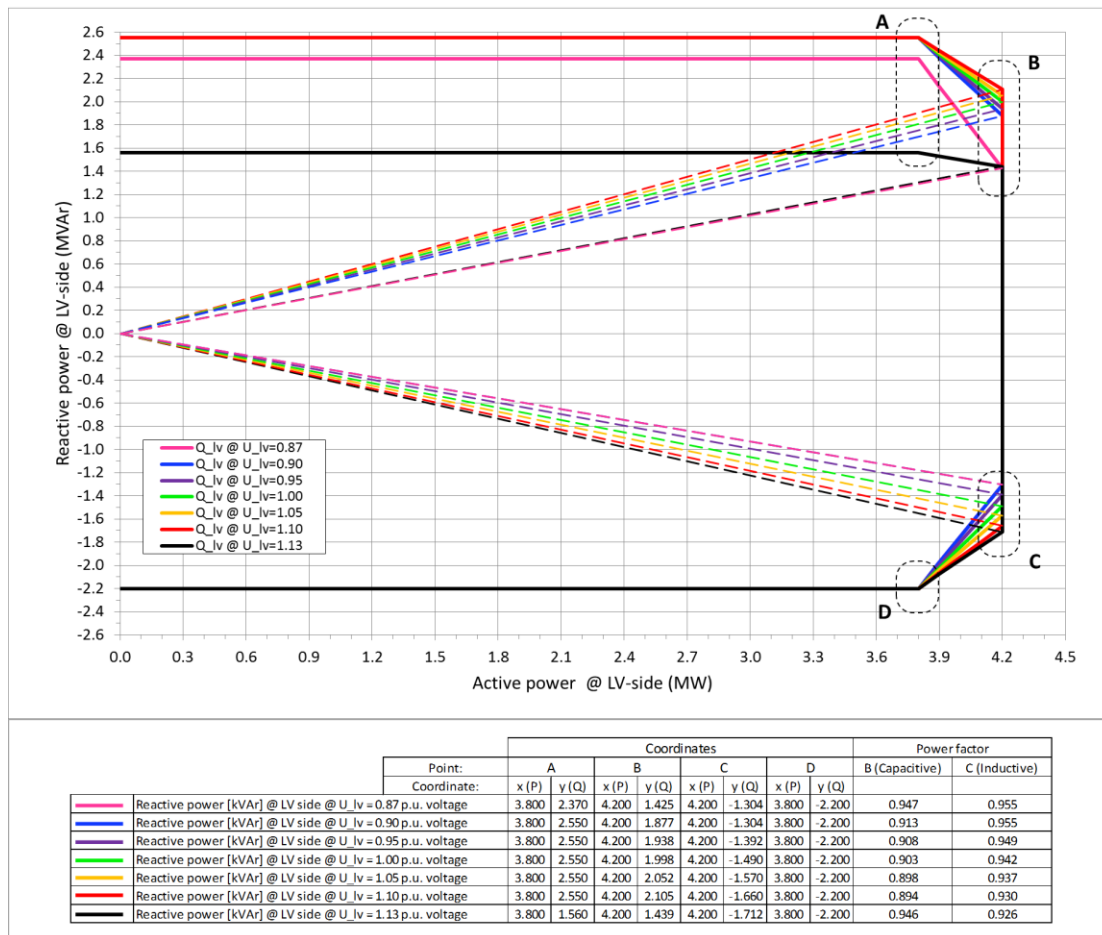


Figure 10-5: Reactive power capability for 4.2 MW Power Optimized Mode (PO1).

When operating at 4.2 MW in Power Optimized Mode (PO1) at LV side of the HV transformer, the reactive power capability on the high voltage side of the HV transformer is approximately:

- $\cos\phi(\text{HV}) = 0.95/0.91$  capacitive/inductive @  $U(\text{HV}) = 0.90$  p.u. voltage
- $\cos\phi(\text{HV}) = 0.94/0.88$  capacitive/inductive @  $U(\text{HV}) = 1.10$  p.u. voltage

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

**NOTE** 4.2 MW Power Optimized Mode (PO1) is mutually exclusive with 4.0 MW Reactive Power Optimized Mode (QO1) (since Q is traded for P).

### 10.8 Operational Envelope – Temperature dependent Reactive Power Capability

The reactive power capabilities shown in Figure 10-3, Figure 10-4 and Figure 10-5 are valid for ambient temperatures at which no active power derate is needed according to **Error! Reference source not found.** and **Error! Reference source not found.**

For ambient temperatures up to 40°C, where active power is derated as a consequence of ambient temperature, the shape of the PQ chart (E.g. Figure 10-3: A, B, C and D points) is maintained. The active power for the A, B, C and D points is however adjusted according to the overall WTG active power derate according to Figure 10-1 and Figure 10-2.

For ambient temperatures between 40°C and 45°C, reactive power is derated proportional to the active power derate.

Figure 10-6 shows an illustrative example of the reactive power derate.

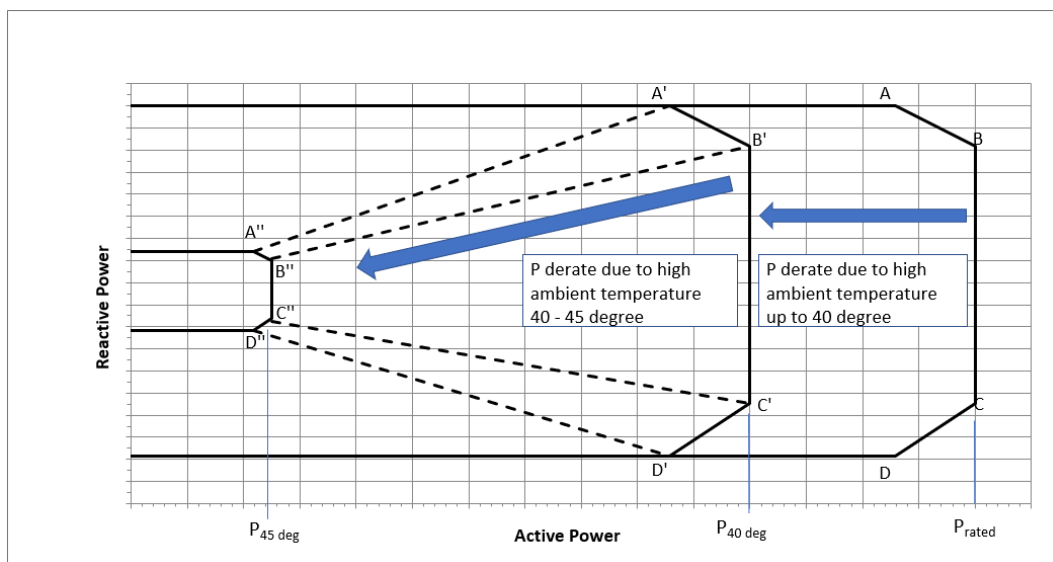


Figure 10-6: Reactive power capability temperature dependency. Illustrative example.



## 10.9 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 below:

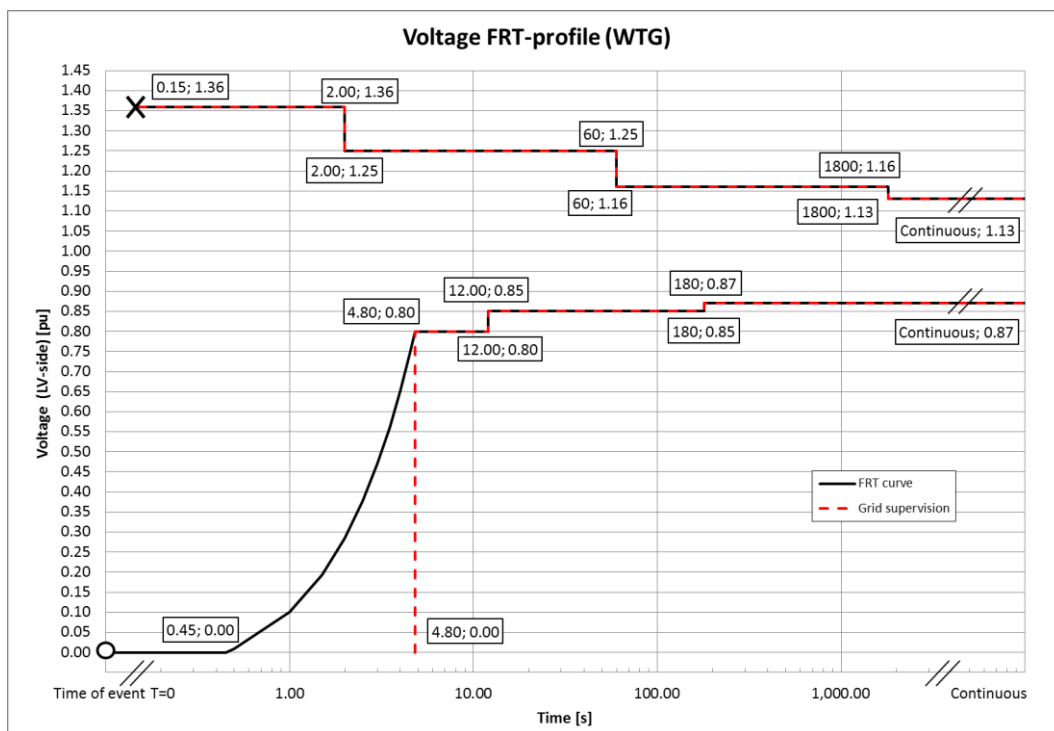


Figure 10-7: Voltage tolerance curve for symmetrical and asymmetrical faults, where U represents voltage as measured on the grid.

For grid disturbances outside the tolerance curve in Figure 10-7, 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

## 10.10 Performance – Reactive Current Contribution

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

During symmetrical voltage dips, the wind farm will inject reactive current to support the grid voltage. The reactive current injected is a function of the 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 10-8, 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 10-8, 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.

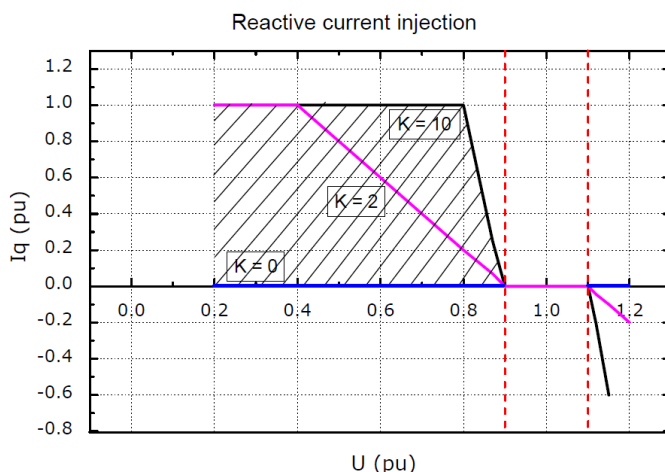


Figure 10-8: Reactive current injection

### 10.10.1 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.

## 10.11 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.

## 10.12 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	
<b>Active Power</b>	0.1 p.u./sec for max. power level change of 0.3 p.u. 0.3 p.u./sec for max. power level change of 0.1 p.u.
<b>Reactive Power</b>	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.

## 10.13 Performance – Voltage Control

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

## 10.14 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.

## 10.15 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%.

## 10.16 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 components in Table 10-7 have the largest influence on the own consumption of the wind turbine (the average own consumption depends on the actual conditions, the climate, the wind turbine output, the cut-off hours, etc.).

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.



<b>Main contributors to Own Consumption</b>	
<b>Hydraulic Motor</b>	2 x 15 (V117) / 18.5 kW (V136 + V150) (master-slave)
<b>Yaw Motors</b>	Maximum 21 kW in total
<b>Water Heating</b>	10 kW
<b>Water Pumps</b>	2.2 + 5.5 kW
<b>Oil Heating</b>	7.9 kW
<b>Oil Pump for Gearbox Lubrication</b>	12.5 kW
<b>Controller Including Heating Elements for the Hydraulics and all Controllers</b>	Approximately 3 kW
<b>HV Transformer No-load Loss</b>	See section 4.3 HV Transformer, p. 14

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

## 11 Drawings

### 11.1 Structural Design – Illustration of Outer Dimensions

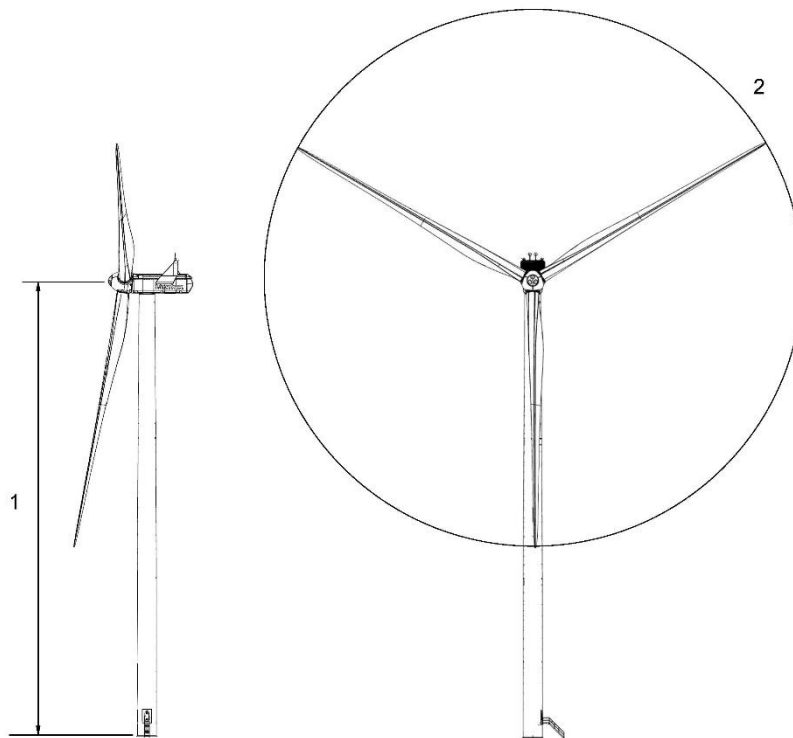


Figure 11-1: Illustration of outer dimensions – structure

- 1 Hub heights: See Performance Specification
- 2 Rotor diameter: 117-150 m

### 11.2 Structural Design – Side View Drawing

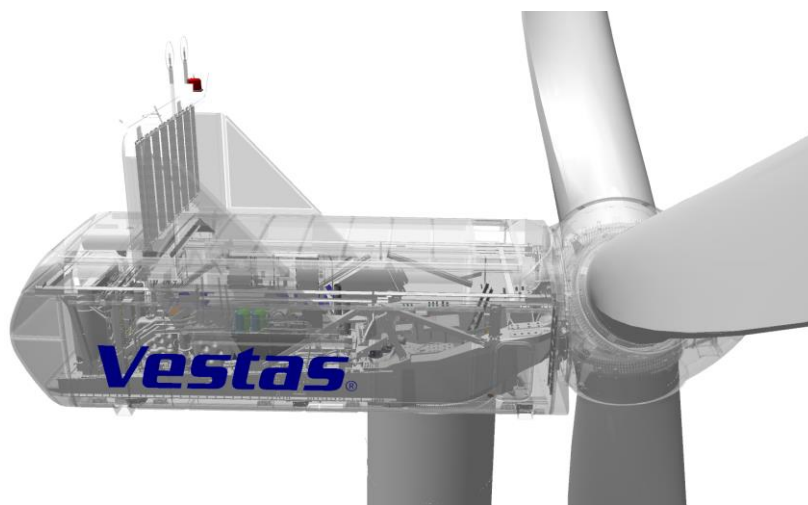


Figure 11-2: Side-view drawing



## 12 General Reservations, Notes and Disclaimers

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- The general descriptions in this document apply to the current version of the 4MW Platform wind turbines. Updated versions of the 4MW Platform wind turbines, which may be manufactured in the future, may differ from this general description. In the event that Vestas supplies an updated version of a specific 4MW Platform wind turbine, Vestas will provide an updated general description applicable to the updated version.
- Vestas recommends that the grid be as close to nominal as possible with limited variation in frequency and voltage.
- A certain time allowance for turbine warm-up must be expected following grid dropout and/or periods of very low ambient temperature.
- All listed start/stop parameters (e. g. wind speeds and temperatures) are equipped with hysteresis control. This can, in certain borderline situations, result in turbine stops even though the ambient conditions are within the listed operation parameters.
- The earthing system must comply with the minimum requirements from Vestas, and be in accordance with local and national requirements and codes of standards.
- This document, General Description, is not an offer for sale, and does not contain any guarantee, warranty and/or verification of the power curve and noise (including, without limitation, the power curve and noise verification method). Any guarantee, warranty and/or verification of the power curve and noise (including, without limitation, the power curve and noise verification method) must be agreed to separately in writing.

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2020-09-29

# Performance Specification

## V136-4.0/4.2 MW 50/60 Hz (Low HH)



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## 1 General Description

The Vestas V136-4.0/4.2 MW wind turbine is a pitch regulated upwind turbine with active yaw and a three-blade rotor. The Vestas V136-4.0/4.2 MW turbine has a rotor diameter of 136 m and a rated power of 4.0 MW.

Vestas offers an optional Power Optimized (PO) mode at 4.2 MW for the V136-4.0 MW variant.

## 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
<b>Tower type</b>		<b>Standard</b>
<b>IEC61400-22</b>	IEC IIB	82 m <sup>(1)</sup>

Table 2-1: Type approval data and available hub heights

<sup>(1)</sup>: Special transport optimized tower for US/Canada.

The hub height can be increased by up to 3 m by use of raised foundation. Use of raised foundation is subject to site-specific evaluation and is not available for all soil conditions.

## 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 IIB	IEC S
<b>Hub Height</b>	<b>82 m</b>	<b>82 m</b>
<b>Power Rating</b>	<b>4.0MW</b>	<b>4.2MW</b>
<b>Extr Wind Speed (10 min average), <math>V_{50}</math></b>	42.5 m/s	42.5 m/s
<b>Survival Wind Speed (3 s gust), <math>V_{e50}</math></b>	59.5 m/s	59.5 m/s
<b>Turbulence Intensity, <math>I_{v50}</math></b>	11%	11%

Table 3-1: Extreme design parameters – IEC

Wind Climate	IEC IIB	IEC S
Hub Height	82 m	82 m
Power Rating	4.0MW	4.2MW
Wind Speed (10 min average), $V_{ave}$	8.5 m/s	8.0 m/s
Weibull Scale Factor, $C$	9.6 m/s	8.9 m/s
Weibull Shape Factor, $k$	2.0	2.0
$I_{ref}$ acc. to IEC 61400-1	0.14	0.14
Turbulence Intensity acc. to IEC 61400-1, Including Wind Farm Turbulence (@15 m/s) $I_{90}$ (90% quantile)	15.7%	15.7%
Wind Shear, $\alpha$	0.20	0.20
Inflow Angle (vertical)	8°	8°

Table 3-2: Average design parameters – IEC

### 3.1.1 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 Vestas Site Check.

### 3.1.2 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.

### 3.1.3 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 IIB
Hub Height	82 m
Cut-In, $V_{in}$	3 m/s
Cut-Out (10 min exponential avg.), $V_{out}$	27.0 m/s
Re-Cut In (10 min exponential avg.)	25.0 m/s

Table 3-3: Operational envelope – wind – IEC

### 3.3 Operational Envelope – Wind (HWO)

Optionally, the turbine can be offered with the High Wind Operation (HWO) control feature. The HWO control feature allows the turbine to operate up to the extended cut-out wind speeds listed in Table 3-4, p. 7, with a controlled derating of power and speed. The power curves associated with optional HWO control are found in Sections 7, 9, 11 and 13. Values refer to hub height and are determined by the sensors and control system of the turbine.

Wind climate	IEC IIB
Hub height	82 m
Cut-In, $V_{in}$	3 m/s
Cut-Out (10 min exponential avg.), $V_{out}$	32.0 m/s
Re-Cut In (10 min exponential avg.)	30.0 m/s

Table 3-4: Operational envelope – wind – IEC (High Wind Operation)

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

Consult Section 6 and following sections for power curves and  $C_t$  values.

Conditions for Power Curve and $C_t$ Values (at Hub Height)	
Wind Shear, $\alpha$	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)	$0 \pm 2^\circ$
Grid Voltage	Nominal Voltage $\pm 2.5\%$
Grid Frequency	Nominal Frequency $\pm 0.5$ Hz
Grid Active Power (LV-side of turbine transformer)	As per tabulated values from Section 6 onwards
Grid Reactive Power (LV-side of turbine transformer)	Power Factor 1.0

Table 3-5: Conditions for power curve and  $C_t$  values

### 3.5 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
0/PO1	103.9 dBA	Yes (standard)	82 m
0-0S/ PO1-0S	106.9 dBA	No (option)	82 m

Table 3-6: Available sound performance

**NOTE** The turbine is as standard equipped with serrated trailing edges on the blades. Optionally, Mode 0-0S/PO1-0S can be offered without serrated trailing edges mounted on the blades.

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
SO1	102.0 dBA	Yes	82 m
SO2	99.5 dBA	Yes	82 m
SO11	99.2 dBA	Yes	82 m <sup>(1)</sup>
SO12	99.9 dBA	Yes	82 m <sup>(1)</sup>
SO13	97.0 dBA	Yes	82 m <sup>(1)</sup>

Table 3-7: Available Sound Optimized modes

<sup>(1)</sup>: SO11, SO12, SO13 is not applicable for DIBt towers

**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 for sound modes per tower, please contact Vestas Wind Systems A/S.

### 3.6 Load Modes

The Load Optimized (LO) modes listed below are available for the turbine.

Load Optimized (LO) modes				
Mode No.	Power	Maximum Sound Level	Serrated trailing edges	Available hub heights
LO1	3.8 MW	103.9 dBA	Yes	82 m
LO2	3.6 MW	103.9 dBA	Yes	82 m

Table 3-8: Available Load Optimized modes

**NOTE** Load Optimized (LO) modes are only available with serrated trailing edges mounted on the blades.

## 4 Drawings

### 4.1 Structural Design – Illustration of Outer Dimensions

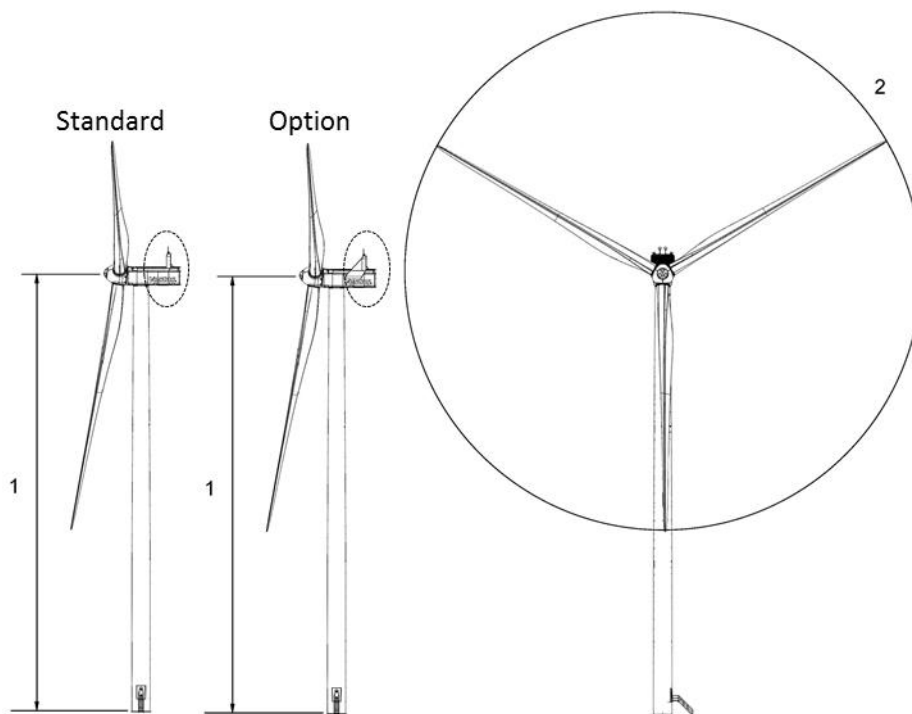


Figure 4-1: Illustration of outer dimensions – structure

**1** Hub height:  
82 m

**2** Diameter:  
136 m

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**NOTE** The turbine to the right is shown with side panels on the cooler top (Option).

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## 5 General Reservations, Notes and Disclaimers

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- The performance specifications described in this document apply to the current version of the V136-4.0/4.2 MW wind turbine. Updated versions of the V136-4.0/4.2 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 V136-4.0/4.2 MW wind, 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 0/0-0S

**NOTE** The power curves and Ct values presented in Section 6 are only valid for low hub heights, i.e. hub heights ≤ 104 m.

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

Air density [kg/m <sup>3</sup> ]														
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	55	31	33	35	38	40	42	44	46	48	51	53	57	59
3.5	130	89	93	97	100	104	108	111	115	119	122	126	133	137
4.0	220	159	165	170	176	182	187	193	198	204	209	215	226	231
4.5	331	245	253	260	268	276	284	292	299	307	315	323	338	346
5.0	471	353	364	374	385	396	407	417	428	439	449	460	481	492
5.5	639	483	497	511	526	540	554	568	582	596	610	624	653	667
6.0	841	640	659	677	695	714	732	750	768	787	805	823	860	878
6.5	1080	826	849	872	895	919	942	965	988	1011	1034	1057	1104	1127
7.0	1361	1044	1073	1102	1131	1160	1189	1218	1247	1276	1304	1333	1390	1419
7.5	1681	1293	1329	1364	1399	1435	1470	1505	1541	1576	1611	1646	1715	1750
8.0	2042	1578	1620	1663	1706	1748	1790	1833	1875	1917	1959	2000	2083	2124
8.5	2441	1897	1947	1998	2048	2099	2148	2198	2247	2296	2345	2393	2488	2535
9.0	2845	2242	2300	2358	2415	2473	2527	2582	2636	2691	2742	2794	2894	2943
9.5	3214	2591	2652	2713	2774	2836	2892	2948	3004	3060	3111	3163	3263	3311
10.0	3547	2923	2985	3048	3110	3172	3228	3284	3340	3396	3447	3497	3592	3637
10.5	3809	3228	3290	3354	3416	3480	3532	3585	3638	3691	3731	3770	3838	3867
11.0	3949	3504	3561	3618	3676	3733	3772	3810	3849	3888	3908	3929	3960	3972
11.5	3992	3739	3781	3824	3866	3908	3925	3942	3959	3976	3981	3986	3994	3996
12.0	3999	3902	3921	3940	3960	3979	3983	3988	3992	3996	3997	3998	3999	4000
12.5	4000	3970	3977	3983	3990	3996	3997	3998	3999	4000	4000	4000	4000	4000
13.0	4000	3992	3994	3996	3997	3999	4000	4000	4000	4000	4000	4000	4000	4000
13.5	4000	3994	3995	3997	3998	3999	4000	4000	4000	4000	4000	4000	4000	4000
14.0	4000	3998	3998	3999	3999	4000	4000	4000	4000	4000	4000	4000	4000	4000
14.5	4000	3999	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
15.0	4000	3999	3999	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
15.5	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
16.0	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
16.5	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
17.0	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
17.5	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
18.0	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
18.5	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
19.0	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
19.5	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
20.0	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
20.5	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
21.0	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
21.5	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
22.0	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
22.5	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
23.0	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
23.5	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
24.0	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
24.5	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
25.0	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
25.5	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
26.0	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
26.5	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
27.0	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000

Table 6-1: Power curve, Mode 0/0-0S

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

Air density kg/m <sup>3</sup>														
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	0.873	0.878	0.877	0.877	0.876	0.876	0.876	0.875	0.875	0.874	0.874	0.874	0.873	0.873
3.5	0.847	0.851	0.851	0.850	0.850	0.850	0.849	0.849	0.849	0.848	0.848	0.848	0.847	0.846
4.0	0.845	0.854	0.853	0.851	0.850	0.848	0.848	0.848	0.847	0.847	0.847	0.846	0.845	0.845
4.5	0.843	0.842	0.842	0.843	0.843	0.843	0.843	0.843	0.844	0.844	0.843	0.843	0.843	0.843
5.0	0.844	0.848	0.848	0.848	0.847	0.847	0.847	0.846	0.846	0.846	0.845	0.845	0.844	0.843
5.5	0.840	0.845	0.845	0.844	0.844	0.843	0.843	0.842	0.842	0.841	0.841	0.840	0.839	0.839
6.0	0.834	0.840	0.840	0.839	0.839	0.838	0.838	0.837	0.836	0.836	0.835	0.835	0.834	0.833
6.5	0.828	0.836	0.835	0.835	0.834	0.833	0.833	0.832	0.831	0.831	0.830	0.829	0.827	0.827
7.0	0.821	0.831	0.830	0.829	0.828	0.828	0.827	0.826	0.825	0.824	0.823	0.822	0.820	0.819
7.5	0.814	0.825	0.824	0.823	0.822	0.822	0.820	0.819	0.818	0.817	0.816	0.815	0.813	0.812
8.0	0.816	0.830	0.829	0.828	0.826	0.825	0.824	0.823	0.821	0.820	0.819	0.817	0.814	0.812
8.5	0.799	0.831	0.829	0.827	0.825	0.823	0.820	0.816	0.813	0.810	0.806	0.803	0.795	0.791
9.0	0.746	0.807	0.802	0.798	0.793	0.788	0.782	0.776	0.771	0.765	0.759	0.752	0.739	0.733
9.5	0.675	0.753	0.746	0.739	0.732	0.725	0.718	0.711	0.704	0.696	0.689	0.682	0.668	0.661
10.0	0.607	0.688	0.680	0.672	0.665	0.657	0.650	0.643	0.636	0.628	0.621	0.614	0.600	0.593
10.5	0.542	0.626	0.619	0.611	0.604	0.597	0.589	0.582	0.575	0.567	0.559	0.551	0.534	0.525
11.0	0.473	0.570	0.562	0.554	0.546	0.538	0.530	0.521	0.512	0.503	0.493	0.483	0.464	0.454
11.5	0.406	0.518	0.508	0.499	0.489	0.480	0.469	0.458	0.448	0.437	0.427	0.416	0.397	0.388
12.0	0.349	0.464	0.453	0.441	0.430	0.418	0.408	0.397	0.386	0.376	0.367	0.358	0.341	0.333
12.5	0.303	0.408	0.396	0.385	0.374	0.362	0.353	0.344	0.335	0.325	0.318	0.310	0.296	0.290
13.0	0.266	0.356	0.346	0.336	0.326	0.316	0.308	0.300	0.292	0.285	0.278	0.272	0.260	0.255
13.5	0.236	0.313	0.305	0.296	0.288	0.279	0.273	0.266	0.259	0.253	0.247	0.242	0.232	0.227
14.0	0.210	0.277	0.269	0.262	0.255	0.248	0.242	0.236	0.230	0.225	0.220	0.215	0.206	0.202
14.5	0.188	0.246	0.240	0.234	0.227	0.221	0.216	0.211	0.206	0.201	0.197	0.193	0.185	0.181
15.0	0.169	0.220	0.214	0.209	0.203	0.198	0.193	0.189	0.184	0.180	0.176	0.173	0.166	0.162
15.5	0.153	0.198	0.193	0.188	0.183	0.178	0.174	0.170	0.167	0.163	0.159	0.156	0.150	0.147
16.0	0.139	0.179	0.175	0.170	0.166	0.162	0.158	0.155	0.151	0.148	0.145	0.142	0.136	0.134
16.5	0.127	0.163	0.159	0.155	0.151	0.147	0.144	0.141	0.138	0.135	0.132	0.129	0.124	0.122
17.0	0.116	0.149	0.145	0.142	0.138	0.135	0.132	0.129	0.126	0.123	0.121	0.118	0.114	0.112
17.5	0.107	0.136	0.133	0.130	0.126	0.123	0.121	0.118	0.116	0.113	0.111	0.109	0.105	0.103
18.0	0.098	0.125	0.122	0.119	0.116	0.113	0.111	0.109	0.106	0.104	0.102	0.100	0.096	0.095
18.5	0.091	0.115	0.113	0.110	0.107	0.105	0.103	0.100	0.098	0.096	0.094	0.093	0.089	0.088
19.0	0.084	0.106	0.104	0.101	0.099	0.096	0.094	0.093	0.091	0.089	0.087	0.085	0.082	0.081
19.5	0.078	0.098	0.096	0.094	0.092	0.089	0.088	0.086	0.084	0.082	0.081	0.079	0.077	0.075
20.0	0.073	0.091	0.089	0.087	0.085	0.083	0.082	0.080	0.078	0.077	0.075	0.074	0.071	0.070
20.5	0.068	0.085	0.083	0.081	0.079	0.078	0.076	0.075	0.073	0.072	0.070	0.069	0.067	0.065
21.0	0.063	0.079	0.078	0.076	0.074	0.073	0.071	0.070	0.068	0.067	0.066	0.065	0.062	0.061
21.5	0.060	0.075	0.073	0.072	0.070	0.069	0.067	0.066	0.065	0.063	0.062	0.061	0.059	0.058
22.0	0.056	0.070	0.069	0.067	0.066	0.064	0.063	0.062	0.061	0.059	0.058	0.057	0.056	0.055
22.5	0.053	0.066	0.065	0.063	0.062	0.060	0.059	0.058	0.057	0.056	0.055	0.054	0.052	0.051
23.0	0.050	0.062	0.060	0.059	0.058	0.057	0.056	0.055	0.054	0.052	0.052	0.051	0.049	0.048
23.5	0.047	0.058	0.057	0.056	0.055	0.053	0.052	0.052	0.051	0.050	0.049	0.048	0.046	0.046
24.0	0.045	0.055	0.054	0.053	0.052	0.051	0.050	0.049	0.048	0.047	0.046	0.045	0.044	0.043
24.5	0.042	0.052	0.051	0.050	0.049	0.048	0.047	0.046	0.045	0.044	0.044	0.043	0.042	0.041
25.0	0.040	0.049	0.048	0.047	0.046	0.045	0.045	0.044	0.043	0.042	0.042	0.041	0.040	0.039
25.5	0.038	0.047	0.046	0.045	0.044	0.043	0.043	0.042	0.041	0.040	0.040	0.039	0.038	0.037
26.0	0.037	0.045	0.044	0.043	0.042	0.041	0.040	0.040	0.039	0.038	0.038	0.037	0.036	0.036
26.5	0.035	0.042	0.042	0.041	0.040	0.039	0.039	0.038	0.037	0.037	0.036	0.035	0.034	0.034
27.0	0.033	0.041	0.040	0.039	0.038	0.037	0.037	0.036	0.036	0.035	0.034	0.034	0.033	0.032

Table 6-2: C<sub>t</sub> values, Mode 0/0-0S

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

Sound Power Level at Hub Height		
Conditions for Sound Power Level:	Measurement standard IEC 61400-11 ed. 3 Maximum turbulence at hub height: 30% Inflow angle (vertical): 0 ±2° Air density: 1.225 kg/m <sup>3</sup>	
Wind speed at hub height [m/s]	Sound Power Level at Hub Height [dBA] Mode 0 (Blades with serrated trailing edge)	Sound Power Level at Hub Height [dBA] Mode 0-0S (Blades without serrated trailing edge)
3	90.9	93.1
4	91.1	93.6
5	92.8	96.4
6	95.9	99.9
7	99.5	103.1
8	102.8	105.9
9	103.9	106.9
10	103.9	106.9
11	103.9	106.9
12	103.9	106.9
13	103.9	106.9
14	103.9	106.9
15	103.9	106.9
16	103.9	106.9
17	103.9	106.9
18	103.9	106.9
19	103.9	106.9
20	103.9	106.9

Table 6-3: Sound curves, Mode 0/0-0S

## 7 Power Curves, Ct Values and Sound Curves, Mode 0/0-0S (HWO)

**NOTE** The power curves and Ct values presented in Section 7 are only valid for low hub heights, i.e. hub heights ≤ 104 m.

### 7.1 Power Curves, Mode 0/0-0S (HWO)

Air density [kg/m <sup>3</sup> ]														
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	55	31	33	35	38	40	42	44	46	48	51	53	57	59
3.5	130	89	93	97	100	104	108	111	115	119	122	126	133	137
4.0	220	159	165	170	176	182	187	193	198	204	209	215	226	231
4.5	331	245	253	260	268	276	284	292	299	307	315	323	338	346
5.0	471	353	364	374	385	396	407	417	428	439	449	460	481	492
5.5	639	483	497	511	526	540	554	568	582	596	610	624	653	667
6.0	841	640	659	677	695	714	732	750	768	787	805	823	860	878
6.5	1080	826	849	872	895	919	942	965	988	1011	1034	1057	1104	1127
7.0	1361	1044	1073	1102	1131	1160	1189	1218	1247	1276	1304	1333	1390	1419
7.5	1681	1293	1329	1364	1399	1435	1470	1505	1541	1576	1611	1646	1715	1750
8.0	2042	1578	1620	1663	1706	1748	1790	1833	1875	1917	1959	2000	2083	2124
8.5	2441	1897	1947	1998	2048	2099	2148	2198	2247	2296	2345	2393	2488	2535
9.0	2845	2242	2300	2358	2415	2473	2527	2582	2636	2691	2742	2794	2894	2943
9.5	3214	2591	2652	2713	2774	2836	2892	2948	3004	3060	3111	3163	3263	3311
10.0	3547	2923	2985	3048	3110	3172	3228	3284	3340	3396	3447	3497	3592	3637
10.5	3809	3228	3290	3354	3416	3480	3532	3585	3638	3691	3731	3770	3838	3867
11.0	3949	3504	3561	3618	3676	3733	3772	3810	3849	3888	3908	3929	3960	3972
11.5	3992	3739	3781	3824	3866	3908	3925	3942	3959	3976	3981	3986	3994	3996
12.0	3999	3902	3921	3940	3960	3979	3983	3988	3992	3996	3997	3998	3999	4000
12.5	4000	3970	3977	3983	3990	3996	3997	3998	3999	4000	4000	4000	4000	4000
13.0	4000	3992	3994	3996	3997	3999	4000	4000	4000	4000	4000	4000	4000	4000
13.5	4000	3994	3995	3997	3998	3999	4000	4000	4000	4000	4000	4000	4000	4000
14.0	4000	3998	3998	3999	3999	4000	4000	4000	4000	4000	4000	4000	4000	4000
14.5	4000	3999	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
15.0	4000	3999	3999	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
15.5	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
16.0	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
16.5	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
17.0	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
17.5	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
18.0	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
18.5	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
19.0	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
19.5	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
20.0	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
20.5	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
21.0	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
21.5	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
22.0	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
22.5	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
23.0	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
23.5	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
24.0	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
24.5	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
25.0	3998	3998	3998	3998	3998	3998	3998	3998	3998	3998	3998	3998	3998	3998
25.5	3976	3976	3976	3976	3976	3976	3976	3976	3976	3976	3976	3976	3976	3976
26.0	3928	3928	3928	3928	3928	3928	3928	3928	3928	3928	3928	3928	3928	3928
26.5	3857	3857	3857	3857	3857	3857	3857	3857	3857	3857	3857	3857	3857	3857
27.0	3763	3763	3763	3763	3763	3763	3763	3763	3763	3763	3763	3763	3763	3763
27.5	3630	3630	3630	3630	3630	3630	3630	3630	3630	3630	3630	3630	3630	3630
28.0	3468	3468	3468	3468	3468	3468	3468	3468	3468	3468	3468	3468	3468	3468

<b>Air density [kg/m<sup>3</sup>]</b>														
<b>Wind speed [m/s]</b>	<b>1.225</b>	<b>0.950</b>	<b>0.975</b>	<b>1.000</b>	<b>1.025</b>	<b>1.050</b>	<b>1.075</b>	<b>1.100</b>	<b>1.125</b>	<b>1.150</b>	<b>1.175</b>	<b>1.200</b>	<b>1.250</b>	<b>1.275</b>
<b>28.5</b>	<b>3275</b>	3275	3275	3275	3275	3275	3275	3275	3275	3275	3275	3275	3275	3275
<b>29.0</b>	<b>3049</b>	3049	3049	3049	3049	3049	3049	3049	3049	3049	3049	3049	3049	3049
<b>29.5</b>	<b>2806</b>	2806	2806	2806	2806	2806	2806	2806	2806	2806	2806	2806	2806	2806
<b>30.0</b>	<b>2565</b>	2565	2565	2565	2565	2565	2565	2565	2565	2565	2565	2565	2565	2565
<b>30.5</b>	<b>2324</b>	2324	2324	2324	2324	2324	2324	2324	2324	2325	2325	2325	2325	2324
<b>31.0</b>	<b>2090</b>	2090	2090	2090	2090	2090	2090	2090	2090	2090	2090	2090	2090	2090
<b>31.5</b>	<b>1884</b>	1884	1884	1884	1884	1884	1884	1884	1884	1884	1884	1884	1884	1884
<b>32.0</b>	<b>1732</b>	1732	1732	1732	1732	1732	1732	1732	1732	1732	1732	1732	1732	1732

*Table 7-1: Power curve, Mode 0/0-0S (HWO)*



**7.3 Sound Curves, Mode 0/0-0S (HWO)**

Sound Power Level at Hub Height		
Conditions for Sound Power Level:	Measurement standard IEC 61400-11 ed. 3 Maximum turbulence at hub height: 30% Inflow angle (vertical): 0 ±2° Air density: 1.225 kg/m <sup>3</sup>	
Wind speed at hub height [m/s]	Sound Power Level at Hub Height [dBA] Mode 0 (HWO) (Blades with serrated trailing edge)	Sound Power Level at Hub Height [dBA] Mode 0-0S (HWO) (Blades without serrated trailing edge)
3	90.9	93.1
4	91.1	93.6
5	92.8	96.4
6	95.9	99.9
7	99.5	103.1
8	102.8	105.9
9	103.9	106.9
10	103.9	106.9
11	103.9	106.9
12	103.9	106.9
13	103.9	106.9
14	103.9	106.9
15	103.9	106.9
16	103.9	106.9
17	103.9	106.9
18	103.9	106.9
19	103.9	106.9
20	103.9	106.9

Table 7-3: Sound curves, Mode 0/0-0S (HWO)



## 8 Power Curves, Ct Values and Sound Curves, Power Optimized Mode PO1/PO1-0S

**NOTE** The power curves and Ct values presented in Section 8 are only valid for low hub heights, i.e. hub heights ≤ 104 m.

### 8.1 Power Curves, Power Optimized Mode PO1/PO1-0S

Wind speed [m/s]	Air density [kg/m <sup>3</sup> ]													
	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	55	31	33	35	38	40	42	44	46	48	51	53	57	59
3.5	130	89	93	97	100	104	108	111	115	119	122	126	133	137
4.0	220	159	165	170	176	182	187	193	198	204	209	215	226	231
4.5	331	245	253	260	268	276	284	292	299	307	315	323	338	346
5.0	471	353	364	374	385	396	407	417	428	439	449	460	481	492
5.5	639	483	497	512	526	540	554	568	582	596	610	624	653	667
6.0	841	640	659	677	695	714	732	750	768	787	805	823	860	878
6.5	1080	826	849	872	895	919	942	965	988	1011	1034	1057	1104	1127
7.0	1362	1044	1073	1102	1131	1160	1189	1218	1247	1276	1304	1333	1390	1419
7.5	1681	1293	1329	1364	1399	1435	1470	1505	1541	1576	1611	1646	1715	1750
8.0	2042	1578	1620	1663	1706	1748	1790	1833	1875	1917	1959	2000	2083	2124
8.5	2441	1897	1947	1998	2048	2099	2148	2198	2247	2297	2345	2393	2488	2535
9.0	2845	2242	2300	2358	2415	2473	2527	2582	2636	2691	2742	2794	2894	2943
9.5	3214	2591	2652	2713	2774	2836	2891	2947	3003	3059	3111	3162	3262	3311
10.0	3547	2923	2985	3047	3110	3172	3228	3284	3340	3396	3446	3497	3593	3640
10.5	3832	3227	3290	3353	3416	3479	3533	3587	3641	3696	3741	3787	3869	3906
11.0	4025	3504	3563	3623	3682	3742	3788	3833	3879	3924	3958	3992	4051	4077
11.5	4143	3748	3799	3851	3902	3954	3987	4020	4054	4087	4106	4124	4155	4166
12.0	4188	3942	3981	4019	4057	4096	4113	4131	4149	4166	4174	4181	4191	4194
12.5	4198	4074	4097	4119	4142	4164	4171	4179	4186	4193	4195	4197	4199	4199
13.0	4200	4144	4156	4167	4178	4190	4192	4194	4196	4199	4199	4199	4200	4200
13.5	4200	4165	4172	4179	4186	4193	4194	4196	4198	4199	4199	4200	4200	4200
14.0	4200	4183	4187	4190	4194	4198	4198	4199	4199	4200	4200	4200	4200	4200
14.5	4200	4193	4194	4196	4197	4199	4199	4199	4200	4200	4200	4200	4200	4200
15.0	4200	4194	4195	4196	4197	4198	4199	4199	4200	4200	4200	4200	4200	4200
15.5	4200	4196	4197	4198	4198	4199	4199	4200	4200	4200	4200	4200	4200	4200
16.0	4200	4198	4198	4199	4199	4200	4200	4200	4200	4200	4200	4200	4200	4200
16.5	4200	4198	4199	4199	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200
17.0	4200	4199	4199	4199	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200
17.5	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200
18.0	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200
18.5	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200
19.0	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200
19.5	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200
20.0	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200
20.5	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200
21.0	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200
21.5	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200
22.0	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200
22.5	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200
23.0	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200
23.5	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200
24.0	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200
24.5	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200
25.0	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200
25.5	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200
26.0	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200
26.5	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200
27.0	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200

Table 8-1: Power curve, Power Optimized Mode PO1/PO1-0S

## 8.2 Ct Values, Power Optimized Mode PO1/PO1-0S

Air density kg/m <sup>3</sup>														
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	0.873	0.878	0.877	0.877	0.876	0.876	0.876	0.875	0.875	0.874	0.874	0.874	0.873	0.873
3.5	0.847	0.851	0.851	0.850	0.850	0.850	0.849	0.849	0.849	0.848	0.848	0.848	0.847	0.846
4.0	0.845	0.854	0.853	0.851	0.850	0.848	0.848	0.848	0.847	0.847	0.847	0.846	0.845	0.845
4.5	0.843	0.842	0.842	0.843	0.843	0.843	0.843	0.843	0.843	0.844	0.843	0.843	0.843	0.843
5.0	0.844	0.848	0.848	0.848	0.847	0.847	0.847	0.846	0.846	0.845	0.845	0.845	0.844	0.843
5.5	0.840	0.845	0.845	0.844	0.844	0.843	0.843	0.842	0.842	0.841	0.841	0.840	0.839	0.839
6.0	0.834	0.840	0.840	0.839	0.839	0.838	0.838	0.837	0.837	0.836	0.835	0.835	0.834	0.833
6.5	0.828	0.836	0.835	0.835	0.834	0.833	0.833	0.832	0.831	0.831	0.830	0.829	0.827	0.826
7.0	0.821	0.831	0.830	0.829	0.828	0.828	0.827	0.826	0.825	0.824	0.823	0.822	0.820	0.819
7.5	0.814	0.825	0.824	0.823	0.822	0.822	0.820	0.819	0.818	0.817	0.816	0.815	0.813	0.812
8.0	0.816	0.830	0.829	0.828	0.826	0.825	0.824	0.823	0.821	0.820	0.819	0.817	0.814	0.812
8.5	0.799	0.831	0.829	0.827	0.825	0.823	0.820	0.816	0.813	0.810	0.806	0.803	0.795	0.791
9.0	0.746	0.807	0.802	0.798	0.793	0.788	0.782	0.776	0.771	0.765	0.758	0.752	0.739	0.733
9.5	0.675	0.753	0.746	0.739	0.732	0.725	0.718	0.711	0.703	0.696	0.689	0.682	0.668	0.661
10.0	0.607	0.688	0.680	0.672	0.665	0.657	0.650	0.643	0.635	0.628	0.621	0.614	0.601	0.594
10.5	0.546	0.626	0.618	0.611	0.604	0.597	0.589	0.582	0.575	0.568	0.561	0.554	0.539	0.531
11.0	0.484	0.570	0.563	0.555	0.548	0.540	0.532	0.524	0.517	0.509	0.501	0.493	0.476	0.468
11.5	0.425	0.520	0.511	0.503	0.495	0.487	0.478	0.469	0.460	0.452	0.443	0.434	0.416	0.407
12.0	0.369	0.471	0.461	0.452	0.443	0.433	0.424	0.414	0.405	0.395	0.386	0.378	0.361	0.352
12.5	0.320	0.421	0.411	0.401	0.391	0.381	0.372	0.363	0.353	0.344	0.336	0.328	0.313	0.306
13.0	0.281	0.373	0.363	0.353	0.344	0.334	0.326	0.317	0.309	0.301	0.294	0.287	0.275	0.269
13.5	0.249	0.330	0.321	0.312	0.304	0.295	0.288	0.281	0.274	0.267	0.261	0.255	0.244	0.239
14.0	0.221	0.292	0.284	0.277	0.269	0.261	0.255	0.249	0.243	0.237	0.232	0.227	0.217	0.212
14.5	0.198	0.260	0.253	0.246	0.240	0.233	0.228	0.222	0.217	0.212	0.207	0.203	0.194	0.190
15.0	0.178	0.231	0.226	0.220	0.214	0.208	0.203	0.199	0.194	0.189	0.185	0.181	0.174	0.171
15.5	0.161	0.208	0.203	0.198	0.193	0.188	0.183	0.179	0.175	0.171	0.167	0.164	0.157	0.154
16.0	0.146	0.188	0.184	0.179	0.175	0.170	0.166	0.163	0.159	0.155	0.152	0.149	0.143	0.140
16.5	0.133	0.171	0.167	0.163	0.159	0.155	0.151	0.148	0.145	0.141	0.139	0.136	0.130	0.128
17.0	0.122	0.156	0.153	0.149	0.145	0.141	0.138	0.135	0.132	0.129	0.127	0.124	0.119	0.117
17.5	0.112	0.143	0.140	0.136	0.133	0.129	0.127	0.124	0.121	0.119	0.116	0.114	0.110	0.108
18.0	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
18.5	0.095	0.121	0.118	0.115	0.113	0.110	0.108	0.105	0.103	0.101	0.099	0.097	0.093	0.092
19.0	0.088	0.111	0.109	0.106	0.104	0.101	0.099	0.097	0.095	0.093	0.091	0.089	0.086	0.085
19.5	0.081	0.103	0.101	0.098	0.096	0.094	0.092	0.090	0.088	0.086	0.085	0.083	0.080	0.079
20.0	0.076	0.096	0.094	0.091	0.089	0.087	0.085	0.084	0.082	0.080	0.079	0.077	0.075	0.073
20.5	0.071	0.089	0.087	0.085	0.083	0.081	0.080	0.078	0.076	0.075	0.073	0.072	0.070	0.068
21.0	0.066	0.083	0.081	0.080	0.078	0.076	0.074	0.073	0.071	0.070	0.069	0.067	0.065	0.064
21.5	0.063	0.078	0.077	0.075	0.073	0.072	0.070	0.069	0.068	0.066	0.065	0.064	0.062	0.061
22.0	0.059	0.074	0.072	0.070	0.069	0.067	0.066	0.065	0.063	0.062	0.061	0.060	0.058	0.057
22.5	0.055	0.069	0.068	0.066	0.065	0.063	0.062	0.061	0.060	0.058	0.057	0.056	0.055	0.054
23.0	0.052	0.065	0.063	0.062	0.061	0.059	0.058	0.057	0.056	0.055	0.054	0.053	0.051	0.050
23.5	0.049	0.061	0.060	0.058	0.057	0.056	0.055	0.054	0.053	0.052	0.051	0.050	0.048	0.048
24.0	0.047	0.057	0.056	0.055	0.054	0.053	0.052	0.051	0.050	0.049	0.048	0.047	0.046	0.045
24.5	0.044	0.054	0.053	0.052	0.051	0.050	0.049	0.048	0.047	0.046	0.046	0.045	0.043	0.043
25.0	0.042	0.051	0.050	0.049	0.048	0.047	0.046	0.046	0.045	0.044	0.043	0.043	0.041	0.041
25.5	0.040	0.049	0.048	0.047	0.046	0.045	0.044	0.044	0.043	0.042	0.041	0.041	0.039	0.039
26.0	0.038	0.047	0.046	0.045	0.044	0.043	0.042	0.041	0.041	0.040	0.039	0.039	0.038	0.037
26.5	0.036	0.044	0.043	0.043	0.042	0.041	0.040	0.039	0.039	0.038	0.037	0.037	0.036	0.035
27.0	0.035	0.042	0.041	0.041	0.040	0.039	0.038	0.038	0.037	0.036	0.036	0.035	0.034	0.034

Table 8-2: C<sub>t</sub> values, Power Optimized Mode PO1/PO1-0S

**8.3 Sound Curves, Power Optimized Mode PO1/PO1-0S**

Sound Power Level at Hub Height		
Conditions for Sound Power Level:	Measurement standard IEC 61400-11 ed. 3 Maximum turbulence at hub height: 30% Inflow angle (vertical): 0 ±2° Air density: 1.225 kg/m <sup>3</sup>	
Wind speed at hub height [m/s]	Sound Power Level at Hub Height [dBA] Power Optimized Mode PO1 (Blades with serrated trailing edge)	Sound Power Level at Hub Height [dBA] Power Optimized Mode PO1-0S (Blades without serrated trailing edge)
3	90.9	93.1
4	91.1	93.6
5	92.8	96.4
6	95.9	99.9
7	99.5	103.1
8	102.8	105.9
9	103.9	106.9
10	103.9	106.9
11	103.9	106.9
12	103.9	106.9
13	103.9	106.9
14	103.9	106.9
15	103.9	106.9
16	103.9	106.9
17	103.9	106.9
18	103.9	106.9
19	103.9	106.9
20	103.9	106.9

Table 8-3: Sound curves, Power Optimized Mode PO1/PO1-0S

## 9 Power Curves, Ct Values and Sound Curves, Power Optimized Mode PO1/PO1-0S (HWO)

**NOTE** The power curves and Ct values presented in Section 9 are only valid for low hub heights, i.e. hub heights ≤ 104 m.

### 9.1 Power Curves, Power Optimized Mode PO1/PO1-0S (HWO)

Wind speed [m/s]	Air density [kg/m <sup>3</sup> ]													
	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	55	31	33	35	38	40	42	44	46	48	51	53	57	59
3.5	130	89	93	97	100	104	108	111	115	119	122	126	133	137
4.0	220	159	165	170	176	182	187	193	198	204	209	215	226	231
4.5	331	245	253	260	268	276	284	292	299	307	315	323	338	346
5.0	471	353	364	374	385	396	407	417	428	439	449	460	481	492
5.5	639	483	497	512	526	540	554	568	582	596	610	624	653	667
6.0	841	640	659	677	695	714	732	750	768	787	805	823	860	878
6.5	1080	826	849	872	895	919	942	965	988	1011	1034	1057	1104	1127
7.0	1362	1044	1073	1102	1131	1160	1189	1218	1247	1276	1304	1333	1390	1419
7.5	1681	1293	1329	1364	1399	1435	1470	1505	1541	1576	1611	1646	1715	1750
8.0	2042	1578	1620	1663	1706	1748	1790	1833	1875	1917	1959	2000	2083	2124
8.5	2441	1897	1947	1998	2048	2099	2148	2198	2247	2297	2345	2393	2488	2535
9.0	2845	2242	2300	2358	2415	2473	2527	2582	2636	2691	2742	2794	2894	2943
9.5	3214	2591	2652	2713	2774	2836	2891	2947	3003	3059	3111	3162	3262	3311
10.0	3547	2923	2985	3047	3110	3172	3228	3284	3340	3396	3446	3497	3593	3640
10.5	3832	3227	3290	3353	3416	3479	3533	3587	3641	3696	3741	3787	3869	3906
11.0	4025	3504	3563	3623	3682	3742	3788	3833	3879	3924	3958	3991	4051	4077
11.5	4143	3748	3799	3851	3902	3954	3987	4020	4054	4087	4106	4124	4155	4166
12.0	4188	3942	3981	4019	4057	4096	4113	4131	4149	4166	4174	4181	4191	4194
12.5	4198	4074	4097	4119	4142	4164	4171	4179	4186	4193	4195	4197	4199	4199
13.0	4200	4144	4156	4167	4178	4190	4192	4194	4196	4199	4199	4200	4200	4200
13.5	4200	4165	4172	4179	4186	4193	4194	4196	4198	4199	4199	4200	4200	4200
14.0	4200	4183	4187	4190	4194	4198	4198	4199	4199	4200	4200	4200	4200	4200
14.5	4200	4193	4194	4196	4197	4199	4199	4199	4200	4200	4200	4200	4200	4200
15.0	4200	4194	4195	4196	4197	4198	4199	4199	4200	4200	4200	4200	4200	4200
15.5	4200	4196	4197	4198	4198	4199	4199	4200	4200	4200	4200	4200	4200	4200
16.0	4200	4198	4198	4199	4199	4200	4200	4200	4200	4200	4200	4200	4200	4200
16.5	4200	4198	4199	4199	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200
17.0	4200	4199	4199	4199	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200
17.5	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200
18.0	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200
18.5	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200
19.0	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200
19.5	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200
20.0	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200
20.5	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200
21.0	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200
21.5	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200
22.0	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200
22.5	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200
23.0	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200
23.5	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200
24.0	4199	4199	4199	4199	4199	4199	4199	4199	4199	4199	4199	4199	4199	4199
24.5	4189	4189	4189	4189	4189	4189	4189	4189	4189	4189	4189	4189	4189	4189
25.0	4147	4147	4147	4147	4147	4146	4146	4146	4146	4146	4147	4147	4147	4147
25.5	4079	4079	4079	4079	4079	4079	4079	4079	4079	4079	4079	4079	4079	4079
26.0	3984	3984	3984	3984	3984	3984	3984	3984	3984	3984	3984	3984	3984	3984
26.5	3873	3873	3873	3873	3873	3873	3873	3873	3873	3873	3873	3873	3873	3873
27.0	3763	3763	3763	3763	3763	3763	3763	3763	3763	3763	3763	3763	3763	3763
27.5	3629	3629	3629	3629	3629	3629	3629	3629	3629	3629	3629	3629	3629	3629

<b>Air density [kg/m<sup>3</sup>]</b>														
<b>Wind speed [m/s]</b>	<b>1.225</b>	<b>0.950</b>	<b>0.975</b>	<b>1.000</b>	<b>1.025</b>	<b>1.050</b>	<b>1.075</b>	<b>1.100</b>	<b>1.125</b>	<b>1.150</b>	<b>1.175</b>	<b>1.200</b>	<b>1.250</b>	<b>1.275</b>
<b>28.0</b>	<b>3467</b>	3467	3467	3467	3467	3467	3467	3467	3467	3467	3467	3467	3467	3467
<b>28.5</b>	<b>3274</b>	3274	3274	3274	3274	3274	3274	3274	3274	3274	3274	3274	3274	3274
<b>29.0</b>	<b>3048</b>	3048	3048	3048	3048	3048	3048	3048	3048	3048	3048	3048	3048	3048
<b>29.5</b>	<b>2805</b>	2805	2805	2805	2805	2805	2805	2805	2805	2805	2805	2805	2805	2805
<b>30.0</b>	<b>2564</b>	2564	2564	2564	2564	2564	2564	2564	2564	2564	2564	2564	2564	2564
<b>30.5</b>	<b>2324</b>	2324	2324	2324	2324	2324	2324	2324	2324	2324	2324	2324	2324	2324
<b>31.0</b>	<b>2089</b>	2089	2089	2089	2089	2089	2089	2089	2089	2089	2089	2089	2089	2089
<b>31.5</b>	<b>1883</b>	1884	1884	1884	1884	1884	1883	1883	1883	1883	1883	1883	1883	1883
<b>32.0</b>	<b>1732</b>	1732	1731	1731	1731	1731	1731	1731	1731	1732	1732	1732	1732	1732

*Table 9-1: Power curve, Power Optimized Mode PO1/PO1-0S (HWO)*



**9.3 Sound Curves, Power Optimized Mode PO1/PO1-0S (HWO)**

Sound Power Level at Hub Height		
Conditions for Sound Power Level:	Measurement standard IEC 61400-11 ed. 3 Maximum turbulence at hub height: 30% Inflow angle (vertical): 0 ±2° Air density: 1.225 kg/m <sup>3</sup>	
Wind speed at hub height [m/s]	Sound Power Level at Hub Height [dBA] Power Optimized Mode PO1 (HWO) (Blades with serrated trailing edge)	Sound Power Level at Hub Height [dBA] Power Optimized Mode PO1-0S (HWO) (Blades without serrated trailing edge)
3	90.9	93.1
4	91.1	93.6
5	92.8	96.4
6	95.9	99.9
7	99.5	103.1
8	102.8	105.9
9	103.9	106.9
10	103.9	106.9
11	103.9	106.9
12	103.9	106.9
13	103.9	106.9
14	103.9	106.9
15	103.9	106.9
16	103.9	106.9
17	103.9	106.9
18	103.9	106.9
19	103.9	106.9
20	103.9	106.9

Table 9-3: Sound curves, Power Optimized Mode PO1/PO1-0S (HWO)

**10 Power Curves, Ct Values and Sound Curves, Sound Optimized Mode SO1**

**NOTE** The power curves and Ct values presented in Section 10 are only valid for low hub heights, i.e. hub heights ≤ 104 m.

**10.1 Power Curves, Sound Optimized Mode SO1**

Air density [kg/m <sup>3</sup> ]														
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	55	31	33	35	38	40	42	44	46	48	51	53	57	59
3.5	130	89	93	97	100	104	108	111	115	119	122	126	133	137
4.0	220	159	165	170	176	182	187	193	198	204	209	215	226	231
4.5	331	246	253	261	269	277	284	292	300	308	316	324	339	347
5.0	470	352	363	374	385	395	406	417	427	438	449	459	481	491
5.5	638	483	497	511	525	539	553	568	582	596	610	624	652	666
6.0	840	640	658	676	694	713	731	749	768	786	804	822	859	877
6.5	1079	825	848	871	895	918	941	964	987	1010	1033	1056	1102	1125
7.0	1361	1043	1072	1101	1130	1159	1188	1217	1246	1274	1303	1332	1390	1418
7.5	1681	1293	1328	1364	1399	1435	1470	1506	1541	1576	1611	1646	1716	1751
8.0	2039	1574	1617	1659	1702	1744	1787	1829	1871	1914	1955	1997	2080	2122
8.5	2420	1877	1927	1977	2027	2077	2126	2176	2225	2274	2323	2372	2468	2516
9.0	2793	2178	2235	2292	2349	2406	2462	2518	2574	2630	2685	2739	2845	2897
9.5	3119	2458	2521	2584	2647	2710	2771	2831	2892	2953	3008	3064	3168	3218
10.0	3386	2729	2796	2864	2932	2999	3060	3120	3181	3241	3290	3338	3424	3462
10.5	3585	3016	3083	3151	3218	3286	3336	3386	3437	3487	3520	3553	3608	3631
11.0	3716	3278	3337	3396	3456	3515	3551	3587	3622	3658	3677	3697	3726	3736
11.5	3786	3490	3537	3585	3632	3679	3699	3720	3740	3760	3769	3777	3790	3794
12.0	3821	3653	3683	3712	3741	3771	3781	3791	3801	3811	3814	3817	3822	3823
12.5	3840	3758	3774	3789	3805	3820	3824	3829	3833	3837	3838	3839	3841	3842
13.0	3859	3818	3826	3834	3842	3850	3852	3854	3856	3858	3858	3859	3860	3860
13.5	3881	3852	3858	3863	3869	3875	3876	3878	3879	3880	3881	3881	3881	3881
14.0	3900	3886	3889	3892	3895	3898	3899	3899	3900	3900	3900	3900	3900	3900
14.5	3918	3911	3912	3914	3915	3917	3917	3917	3918	3918	3918	3918	3918	3917
15.0	3932	3928	3929	3930	3931	3932	3932	3932	3933	3933	3933	3932	3932	3932
15.5	3945	3943	3943	3944	3945	3945	3945	3946	3946	3946	3946	3945	3945	3945
16.0	3957	3956	3957	3957	3957	3958	3958	3958	3957	3957	3957	3957	3957	3956
16.5	3969	3970	3970	3970	3970	3970	3970	3970	3970	3970	3969	3969	3969	3968
17.0	3981	3982	3982	3982	3983	3983	3982	3982	3982	3982	3982	3981	3981	3981
17.5	3991	3992	3992	3992	3992	3992	3992	3992	3992	3992	3992	3992	3991	3991
18.0	3997	3998	3998	3998	3998	3998	3998	3998	3997	3997	3997	3997	3997	3997
18.5	3999	4000	3999	3999	3999	3999	3999	3999	3999	3999	3999	3999	3999	3999
19.0	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
19.5	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
20.0	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
20.5	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
21.0	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
21.5	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
22.0	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
22.5	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
23.0	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
23.5	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
24.0	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
24.5	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
25.0	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
25.5	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
26.0	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
26.5	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
27.0	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000

Table 10-1: Power curve, Sound Optimized Mode SO1



**10.2 Ct Values, Sound Optimized Mode SO1**

Air density kg/m <sup>3</sup>														
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	0.873	0.878	0.877	0.877	0.876	0.876	0.876	0.875	0.875	0.874	0.874	0.874	0.873	0.873
3.5	0.847	0.851	0.851	0.850	0.850	0.850	0.849	0.849	0.849	0.848	0.848	0.848	0.847	0.846
4.0	0.845	0.854	0.853	0.851	0.850	0.848	0.848	0.848	0.847	0.847	0.847	0.846	0.845	0.845
4.5	0.849	0.848	0.848	0.848	0.849	0.849	0.849	0.849	0.849	0.849	0.849	0.849	0.849	0.848
5.0	0.843	0.847	0.847	0.847	0.847	0.846	0.846	0.846	0.845	0.845	0.844	0.844	0.843	0.842
5.5	0.839	0.845	0.844	0.844	0.843	0.843	0.842	0.842	0.841	0.840	0.840	0.839	0.838	0.838
6.0	0.833	0.840	0.839	0.839	0.838	0.838	0.837	0.837	0.836	0.835	0.835	0.834	0.833	0.832
6.5	0.830	0.838	0.837	0.836	0.836	0.835	0.834	0.833	0.833	0.832	0.831	0.830	0.829	0.828
7.0	0.832	0.841	0.841	0.840	0.839	0.838	0.837	0.836	0.835	0.835	0.834	0.833	0.831	0.830
7.5	0.835	0.846	0.845	0.844	0.843	0.842	0.841	0.840	0.839	0.838	0.837	0.836	0.834	0.833
8.0	0.827	0.839	0.838	0.837	0.836	0.835	0.834	0.832	0.831	0.830	0.829	0.828	0.825	0.824
8.5	0.787	0.801	0.800	0.799	0.798	0.797	0.796	0.795	0.794	0.793	0.791	0.789	0.784	0.782
9.0	0.720	0.736	0.736	0.735	0.734	0.733	0.732	0.730	0.729	0.727	0.725	0.723	0.717	0.714
9.5	0.643	0.663	0.662	0.661	0.660	0.660	0.658	0.657	0.655	0.654	0.650	0.647	0.639	0.634
10.0	0.572	0.605	0.604	0.603	0.602	0.600	0.597	0.594	0.591	0.588	0.583	0.577	0.564	0.557
10.5	0.504	0.570	0.567	0.563	0.559	0.555	0.549	0.543	0.536	0.530	0.521	0.512	0.495	0.486
11.0	0.441	0.534	0.527	0.521	0.514	0.507	0.498	0.489	0.480	0.471	0.461	0.451	0.431	0.422
11.5	0.382	0.489	0.480	0.471	0.461	0.452	0.442	0.431	0.421	0.411	0.401	0.392	0.373	0.365
12.0	0.331	0.438	0.427	0.417	0.406	0.396	0.386	0.376	0.366	0.356	0.348	0.340	0.324	0.316
12.5	0.290	0.386	0.376	0.365	0.355	0.345	0.337	0.328	0.319	0.311	0.304	0.297	0.283	0.277
13.0	0.256	0.339	0.330	0.321	0.312	0.303	0.296	0.288	0.281	0.274	0.268	0.262	0.250	0.245
13.5	0.229	0.301	0.293	0.286	0.278	0.270	0.264	0.257	0.251	0.245	0.239	0.234	0.224	0.219
14.0	0.205	0.268	0.262	0.255	0.248	0.241	0.235	0.230	0.224	0.219	0.214	0.209	0.201	0.197
14.5	0.184	0.241	0.234	0.228	0.222	0.216	0.211	0.206	0.202	0.197	0.193	0.188	0.181	0.177
15.0	0.166	0.216	0.210	0.205	0.199	0.194	0.190	0.185	0.181	0.177	0.173	0.170	0.163	0.160
15.5	0.151	0.195	0.190	0.185	0.181	0.176	0.172	0.168	0.164	0.160	0.157	0.154	0.148	0.145
16.0	0.137	0.177	0.173	0.169	0.164	0.160	0.157	0.153	0.150	0.146	0.143	0.140	0.135	0.132
16.5	0.126	0.162	0.158	0.154	0.150	0.146	0.143	0.140	0.137	0.134	0.131	0.128	0.123	0.121
17.0	0.116	0.148	0.145	0.141	0.138	0.134	0.131	0.128	0.126	0.123	0.120	0.118	0.113	0.111
17.5	0.106	0.136	0.133	0.129	0.126	0.123	0.121	0.118	0.115	0.113	0.111	0.109	0.104	0.103
18.0	0.098	0.125	0.122	0.119	0.116	0.113	0.111	0.109	0.106	0.104	0.102	0.100	0.096	0.095
18.5	0.091	0.115	0.113	0.110	0.107	0.105	0.103	0.101	0.098	0.096	0.094	0.093	0.089	0.088
19.0	0.084	0.106	0.104	0.101	0.099	0.096	0.095	0.093	0.091	0.089	0.087	0.085	0.082	0.081
19.5	0.078	0.098	0.096	0.094	0.092	0.090	0.088	0.086	0.084	0.082	0.081	0.079	0.077	0.075
20.0	0.073	0.091	0.089	0.087	0.085	0.083	0.082	0.080	0.078	0.077	0.075	0.074	0.071	0.070
20.5	0.068	0.085	0.083	0.081	0.080	0.078	0.076	0.075	0.073	0.072	0.070	0.069	0.067	0.066
21.0	0.063	0.079	0.078	0.076	0.074	0.073	0.071	0.070	0.068	0.067	0.066	0.065	0.062	0.061
21.5	0.060	0.075	0.073	0.072	0.070	0.069	0.067	0.066	0.065	0.063	0.062	0.061	0.059	0.058
22.0	0.056	0.070	0.069	0.067	0.066	0.064	0.063	0.062	0.061	0.059	0.058	0.057	0.056	0.055
22.5	0.053	0.066	0.065	0.063	0.062	0.060	0.059	0.058	0.057	0.056	0.055	0.054	0.052	0.051
23.0	0.050	0.062	0.060	0.059	0.058	0.057	0.056	0.055	0.054	0.052	0.052	0.051	0.049	0.048
23.5	0.047	0.058	0.057	0.056	0.055	0.053	0.052	0.052	0.051	0.050	0.049	0.048	0.046	0.046
24.0	0.045	0.055	0.054	0.053	0.052	0.051	0.050	0.049	0.048	0.047	0.046	0.045	0.044	0.043
24.5	0.042	0.052	0.051	0.050	0.049	0.048	0.047	0.046	0.045	0.044	0.044	0.043	0.042	0.041
25.0	0.040	0.049	0.048	0.047	0.046	0.045	0.045	0.044	0.043	0.042	0.041	0.041	0.040	0.039
25.5	0.038	0.047	0.046	0.045	0.044	0.043	0.043	0.042	0.041	0.040	0.040	0.039	0.038	0.037
26.0	0.037	0.045	0.044	0.043	0.042	0.041	0.040	0.040	0.039	0.038	0.038	0.037	0.036	0.035
26.5	0.035	0.042	0.042	0.041	0.040	0.039	0.039	0.038	0.037	0.037	0.036	0.035	0.034	0.034
27.0	0.033	0.040	0.040	0.039	0.038	0.037	0.037	0.036	0.035	0.035	0.034	0.034	0.033	0.032

Table 10-2: C<sub>t</sub> values, Sound Optimized Mode SO1

**10.3 Sound Curves, Sound Optimized Mode SO1**

Sound Power Level at Hub Height	
Conditions for Sound Power Level:	Measurement standard IEC 61400-11 ed. 3 Maximum turbulence at hub height: 30% Inflow angle (vertical): 0 ±2° Air density: 1.225 kg/m <sup>3</sup>
Wind speed at hub height [m/s]	Sound Power Level at Hub Height [dBA] Sound Optimized Mode SO1 (Blades with serrated trailing edge)
3	90.9
4	91.1
5	92.8
6	95.9
7	99.4
8	101.5
9	101.9
10	101.8
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

Table 10-3: Sound curves, Sound Optimized Mode SO1

**11 Power Curves, Ct Values and Sound Curves, Sound Optimized Mode SO1 (HWO)**

**NOTE** The power curves and Ct values presented in Section 11 are only valid for low hub heights, i.e. hub heights ≤ 104 m.

**11.1 Power Curves, Sound Optimized Mode SO1 (HWO)**

Wind speed [m/s]	Air density [kg/m <sup>3</sup> ]													
	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	55	31	33	35	38	40	42	44	46	48	51	53	57	59
3.5	130	89	93	97	100	104	108	111	115	119	122	126	133	137
4.0	220	159	165	170	176	182	187	193	198	204	209	215	226	231
4.5	331	246	253	261	269	277	284	292	300	308	316	324	339	347
5.0	470	352	363	374	385	395	406	417	427	438	449	459	481	491
5.5	638	483	497	511	525	539	553	568	582	596	610	624	652	666
6.0	840	640	658	676	694	713	731	749	768	786	804	822	859	877
6.5	1079	825	848	871	895	918	941	964	987	1010	1033	1056	1102	1125
7.0	1361	1043	1072	1101	1130	1159	1188	1217	1246	1274	1303	1332	1390	1418
7.5	1681	1293	1328	1364	1399	1435	1470	1506	1541	1576	1611	1646	1716	1751
8.0	2039	1574	1617	1659	1702	1744	1787	1829	1871	1914	1955	1997	2080	2122
8.5	2420	1877	1927	1977	2027	2077	2126	2176	2225	2274	2323	2372	2468	2516
9.0	2793	2178	2235	2292	2349	2406	2462	2518	2574	2630	2685	2739	2845	2897
9.5	3119	2458	2521	2584	2647	2710	2771	2831	2892	2953	3008	3064	3168	3218
10.0	3386	2729	2796	2864	2932	2999	3060	3120	3181	3241	3290	3338	3424	3462
10.5	3585	3016	3083	3151	3218	3286	3336	3386	3437	3487	3520	3553	3608	3631
11.0	3716	3278	3337	3396	3456	3515	3551	3587	3622	3658	3677	3697	3726	3736
11.5	3786	3490	3537	3585	3632	3679	3699	3720	3740	3760	3769	3777	3790	3794
12.0	3821	3653	3683	3712	3741	3771	3781	3791	3801	3811	3814	3817	3822	3823
12.5	3840	3758	3774	3789	3805	3820	3824	3829	3833	3837	3838	3839	3841	3842
13.0	3859	3818	3826	3834	3842	3850	3852	3854	3856	3858	3858	3859	3860	3860
13.5	3881	3852	3858	3863	3869	3875	3876	3878	3879	3880	3881	3881	3881	3881
14.0	3900	3886	3889	3892	3895	3898	3899	3899	3900	3900	3900	3900	3900	3900
14.5	3918	3911	3912	3914	3915	3917	3917	3917	3918	3918	3918	3918	3918	3917
15.0	3932	3928	3929	3930	3931	3932	3932	3932	3933	3933	3933	3932	3932	3932
15.5	3945	3943	3943	3944	3945	3945	3945	3946	3946	3946	3946	3945	3945	3945
16.0	3957	3956	3957	3957	3957	3958	3958	3958	3957	3957	3957	3957	3957	3956
16.5	3969	3970	3970	3970	3970	3970	3970	3970	3970	3970	3969	3969	3969	3968
17.0	3981	3982	3982	3982	3983	3983	3982	3982	3982	3982	3982	3981	3981	3981
17.5	3991	3992	3992	3992	3992	3992	3992	3992	3992	3992	3992	3992	3991	3991
18.0	3997	3998	3998	3998	3998	3998	3998	3998	3997	3997	3997	3997	3997	3997
18.5	3999	4000	3999	3999	3999	3999	3999	3999	3999	3999	3999	3999	3999	3999
19.0	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
19.5	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
20.0	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
20.5	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
21.0	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
21.5	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
22.0	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
22.5	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
23.0	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
23.5	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
24.0	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
24.5	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
25.0	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
25.5	3999	3999	3999	3999	3999	3999	3999	3999	3999	3999	3999	3999	3999	3999
26.0	3987	3987	3987	3987	3987	3987	3987	3987	3987	3987	3987	3987	3987	3987
26.5	3946	3946	3946	3946	3946	3946	3946	3946	3946	3946	3946	3946	3946	3946
27.0	3882	3882	3882	3882	3882	3882	3882	3882	3882	3882	3882	3882	3882	3882
27.5	3731	3731	3731	3731	3731	3731	3731	3731	3731	3731	3731	3731	3731	3731
28.0	3516	3516	3516	3516	3516	3516	3516	3516	3516	3516	3516	3516	3516	3516

<b>Air density [kg/m<sup>3</sup>]</b>														
<b>Wind speed [m/s]</b>	<b>1.225</b>	<b>0.950</b>	<b>0.975</b>	<b>1.000</b>	<b>1.025</b>	<b>1.050</b>	<b>1.075</b>	<b>1.100</b>	<b>1.125</b>	<b>1.150</b>	<b>1.175</b>	<b>1.200</b>	<b>1.250</b>	<b>1.275</b>
<b>28.5</b>	<b>3279</b>	3279	3279	3279	3279	3279	3279	3279	3279	3279	3279	3279	3279	3279
<b>29.0</b>	<b>3037</b>	3037	3037	3037	3037	3037	3037	3037	3037	3037	3037	3037	3037	3037
<b>29.5</b>	<b>2791</b>	2791	2791	2791	2791	2791	2791	2791	2791	2791	2791	2791	2791	2791
<b>30.0</b>	<b>2549</b>	2549	2549	2549	2549	2549	2549	2549	2549	2549	2549	2549	2549	2549
<b>30.5</b>	<b>2309</b>	2309	2309	2309	2309	2309	2309	2309	2309	2309	2309	2309	2309	2309
<b>31.0</b>	<b>2074</b>	2075	2074	2074	2074	2074	2074	2074	2074	2074	2074	2074	2074	2074
<b>31.5</b>	<b>1869</b>	1870	1870	1870	1870	1870	1870	1870	1870	1870	1869	1869	1869	1869
<b>32.0</b>	<b>1723</b>	1722	1722	1722	1722	1722	1722	1722	1722	1722	1722	1722	1723	1723

*Table 11-1: Power curve, Sound Optimized Mode SO1 (HWO)*



**11.3 Sound Curves, Sound Optimized Mode SO1 (HWO)**

Sound Power Level at Hub Height	
Conditions for Sound Power Level:	Measurement standard IEC 61400-11 ed. 3 Maximum turbulence at hub height: 30% Inflow angle (vertical): 0 ±2° Air density: 1.225 kg/m <sup>3</sup>
Wind speed at hub height [m/s]	Sound Power Level at Hub Height [dBA] Sound Optimized Mode SO1 (HWO) (Blades with serrated trailing edge)
3	90.9
4	91.1
5	92.8
6	95.9
7	99.4
8	101.5
9	101.9
10	101.8
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

Table 11-3: Sound curves, Sound Optimized Mode SO1 (HWO)

## 12 Power Curves, Ct Values and Sound Curves, Sound Optimized Mode SO2

**NOTE** The power curves and Ct values presented in Section 12 are only valid for low hub heights, i.e. hub heights ≤ 104 m.

### 12.1 Power Curves, Sound Optimized Mode SO2

Wind speed [m/s]	Air density [kg/m <sup>3</sup> ]													
	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	55	31	33	35	38	40	42	44	46	48	51	53	57	59
3.5	130	89	93	97	100	104	108	111	115	119	122	126	133	137
4.0	220	159	165	170	176	182	187	193	198	204	209	215	226	231
4.5	331	246	253	261	269	277	284	292	300	308	316	324	339	347
5.0	470	352	363	374	385	395	406	417	427	438	449	459	481	491
5.5	638	483	497	511	525	539	553	568	582	596	610	624	652	666
6.0	841	640	658	676	695	713	731	749	768	786	804	822	859	877
6.5	1079	825	848	871	895	918	941	964	987	1010	1033	1056	1102	1125
7.0	1360	1042	1072	1101	1130	1159	1188	1216	1245	1274	1303	1331	1388	1417
7.5	1655	1285	1320	1356	1391	1426	1461	1496	1531	1565	1595	1625	1680	1705
8.0	1858	1537	1576	1616	1655	1694	1721	1749	1777	1805	1822	1840	1870	1882
8.5	1961	1767	1797	1827	1857	1887	1901	1915	1929	1943	1949	1955	1965	1968
9.0	2027	1940	1955	1970	1985	2000	2005	2010	2015	2020	2022	2024	2027	2028
9.5	2072	2042	2048	2054	2059	2065	2066	2068	2069	2070	2071	2071	2072	2073
10.0	2112	2105	2106	2107	2107	2108	2109	2109	2110	2111	2111	2111	2112	2112
10.5	2146	2156	2154	2152	2151	2149	2148	2148	2147	2146	2146	2146	2145	2145
11.0	2193	2228	2223	2219	2214	2210	2207	2204	2201	2199	2197	2195	2192	2190
11.5	2236	2282	2277	2271	2266	2261	2257	2253	2249	2245	2242	2239	2233	2231
12.0	2291	2341	2335	2330	2325	2319	2315	2311	2307	2302	2299	2295	2288	2285
12.5	2358	2412	2406	2400	2394	2388	2383	2378	2374	2369	2365	2361	2354	2350
13.0	2418	2473	2467	2461	2454	2448	2443	2439	2434	2429	2425	2422	2415	2411
13.5	2471	2522	2516	2510	2504	2498	2493	2489	2485	2481	2477	2474	2468	2464
14.0	2513	2564	2558	2552	2546	2540	2536	2532	2528	2523	2520	2517	2510	2508
14.5	2563	2615	2609	2604	2598	2592	2587	2583	2578	2574	2570	2567	2560	2557
15.0	2667	2712	2707	2702	2698	2693	2689	2685	2682	2678	2674	2671	2664	2660
15.5	2752	2788	2784	2781	2777	2774	2770	2767	2764	2761	2758	2755	2749	2746
16.0	2845	2872	2869	2867	2864	2862	2859	2857	2854	2852	2850	2847	2842	2840
16.5	2920	2938	2936	2935	2933	2932	2930	2929	2927	2926	2924	2922	2918	2916
17.0	2972	2975	2975	2976	2976	2976	2975	2975	2975	2974	2974	2973	2971	2970
17.5	2996	2995	2995	2995	2996	2996	2996	2996	2996	2996	2996	2996	2996	2995
18.0	3005	3004	3005	3005	3005	3005	3005	3005	3005	3005	3005	3005	3005	3005
18.5	3018	3018	3018	3018	3018	3018	3018	3018	3018	3018	3018	3018	3018	3018
19.0	3043	3054	3052	3051	3050	3049	3048	3047	3046	3045	3044	3044	3042	3041
19.5	3085	3099	3098	3097	3096	3095	3094	3092	3091	3090	3088	3087	3084	3083
20.0	3146	3156	3155	3155	3155	3155	3154	3153	3152	3151	3149	3148	3145	3143
20.5	3216	3211	3212	3213	3214	3214	3215	3216	3216	3217	3216	3216	3215	3214
21.0	3273	3257	3259	3261	3263	3265	3266	3268	3269	3270	3271	3272	3273	3274
21.5	3310	3295	3296	3298	3300	3302	3303	3304	3305	3306	3307	3308	3310	3311
22.0	3335	3319	3321	3323	3325	3327	3329	3330	3331	3333	3333	3334	3335	3336
22.5	3363	3346	3348	3350	3352	3354	3355	3357	3358	3360	3361	3362	3363	3364
23.0	3389	3368	3370	3373	3375	3377	3379	3381	3383	3385	3386	3387	3390	3391
23.5	3403	3384	3386	3388	3391	3393	3394	3396	3398	3399	3400	3402	3404	3405
24.0	3412	3394	3396	3398	3400	3402	3403	3405	3406	3408	3409	3410	3413	3414
24.5	3416	3399	3400	3402	3404	3406	3407	3409	3410	3412	3413	3414	3417	3418
25.0	3416	3398	3400	3403	3405	3407	3409	3411	3413	3414	3415	3416	3417	3418
25.5	3404	3378	3381	3384	3386	3389	3391	3394	3396	3398	3400	3402	3405	3407
26.0	3401	3378	3380	3383	3385	3387	3389	3392	3394	3396	3398	3399	3403	3404
26.5	3399	3378	3380	3382	3385	3387	3389	3391	3392	3394	3396	3397	3400	3401
27.0	3381	3365	3366	3368	3369	3371	3372	3374	3375	3377	3378	3379	3382	3383

Table 12-1: Power curve, Sound Optimized Mode SO2

## 12.2 Ct Values, Sound Optimized Mode SO2

Air density kg/m<sup>3</sup>

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	<b>0.873</b>	0.878	0.877	0.877	0.876	0.876	0.876	0.875	0.875	0.874	0.874	0.874	0.873	0.873
3.5	<b>0.847</b>	0.851	0.851	0.850	0.850	0.850	0.849	0.849	0.849	0.848	0.848	0.848	0.847	0.846
4.0	<b>0.845</b>	0.854	0.853	0.851	0.850	0.848	0.848	0.848	0.847	0.847	0.847	0.846	0.845	0.845
4.5	<b>0.849</b>	0.848	0.848	0.848	0.849	0.849	0.849	0.849	0.849	0.849	0.849	0.849	0.849	0.848
5.0	<b>0.843</b>	0.847	0.847	0.847	0.847	0.846	0.846	0.846	0.845	0.845	0.844	0.844	0.843	0.842
5.5	<b>0.839</b>	0.844	0.844	0.843	0.843	0.842	0.842	0.841	0.841	0.840	0.840	0.839	0.838	0.838
6.0	<b>0.840</b>	0.846	0.845	0.845	0.844	0.844	0.843	0.843	0.842	0.841	0.841	0.840	0.839	0.838
6.5	<b>0.836</b>	0.844	0.844	0.843	0.843	0.842	0.841	0.840	0.840	0.839	0.838	0.837	0.836	0.835
7.0	<b>0.836</b>	0.847	0.847	0.846	0.845	0.844	0.843	0.842	0.842	0.841	0.839	0.838	0.833	0.830
7.5	<b>0.790</b>	0.837	0.836	0.835	0.834	0.833	0.829	0.826	0.822	0.818	0.809	0.800	0.779	0.768
8.0	<b>0.659</b>	0.797	0.789	0.781	0.772	0.764	0.750	0.737	0.723	0.710	0.693	0.676	0.643	0.626
8.5	<b>0.529</b>	0.710	0.695	0.679	0.664	0.648	0.630	0.612	0.594	0.576	0.560	0.545	0.516	0.502
9.0	<b>0.435</b>	0.605	0.586	0.567	0.549	0.530	0.516	0.501	0.486	0.471	0.459	0.447	0.425	0.414
9.5	<b>0.366</b>	0.501	0.486	0.471	0.456	0.440	0.429	0.417	0.405	0.394	0.385	0.375	0.358	0.350
10.0	<b>0.313</b>	0.422	0.409	0.397	0.385	0.372	0.363	0.354	0.345	0.336	0.328	0.321	0.307	0.300
10.5	<b>0.271</b>	0.362	0.352	0.341	0.331	0.321	0.313	0.306	0.298	0.290	0.284	0.277	0.266	0.260
11.0	<b>0.239</b>	0.319	0.310	0.301	0.292	0.283	0.276	0.269	0.262	0.255	0.250	0.244	0.234	0.229
11.5	<b>0.211</b>	0.282	0.274	0.266	0.258	0.251	0.244	0.238	0.232	0.226	0.221	0.216	0.207	0.203
12.0	<b>0.190</b>	0.252	0.245	0.238	0.231	0.224	0.219	0.214	0.208	0.203	0.199	0.194	0.186	0.182
12.5	<b>0.172</b>	0.228	0.222	0.216	0.209	0.203	0.199	0.194	0.189	0.184	0.180	0.176	0.168	0.165
13.0	<b>0.157</b>	0.207	0.201	0.196	0.190	0.185	0.180	0.176	0.172	0.167	0.164	0.160	0.153	0.150
13.5	<b>0.143</b>	0.188	0.183	0.178	0.174	0.169	0.165	0.161	0.157	0.153	0.150	0.147	0.140	0.138
14.0	<b>0.131</b>	0.171	0.167	0.162	0.158	0.153	0.150	0.146	0.143	0.139	0.137	0.134	0.128	0.126
14.5	<b>0.120</b>	0.157	0.153	0.149	0.145	0.141	0.138	0.134	0.131	0.128	0.125	0.123	0.118	0.115
15.0	<b>0.112</b>	0.146	0.142	0.139	0.135	0.131	0.128	0.126	0.123	0.120	0.117	0.115	0.110	0.108
15.5	<b>0.105</b>	0.136	0.133	0.129	0.126	0.123	0.120	0.117	0.115	0.112	0.110	0.107	0.103	0.101
16.0	<b>0.099</b>	0.127	0.124	0.121	0.118	0.115	0.113	0.110	0.108	0.105	0.103	0.101	0.097	0.095
16.5	<b>0.093</b>	0.119	0.116	0.113	0.110	0.108	0.105	0.103	0.101	0.099	0.097	0.095	0.091	0.089
17.0	<b>0.087</b>	0.110	0.108	0.105	0.103	0.100	0.098	0.096	0.094	0.092	0.090	0.088	0.085	0.084
17.5	<b>0.080</b>	0.102	0.099	0.097	0.095	0.093	0.091	0.089	0.087	0.085	0.083	0.082	0.079	0.078
18.0	<b>0.074</b>	0.094	0.092	0.090	0.088	0.086	0.084	0.082	0.080	0.079	0.077	0.076	0.073	0.072
18.5	<b>0.069</b>	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
19.0	<b>0.064</b>	0.081	0.080	0.078	0.076	0.074	0.073	0.071	0.070	0.068	0.067	0.066	0.063	0.062
19.5	<b>0.061</b>	0.077	0.075	0.073	0.072	0.070	0.068	0.067	0.066	0.064	0.063	0.062	0.060	0.059
20.0	<b>0.058</b>	0.073	0.071	0.069	0.068	0.066	0.065	0.064	0.062	0.061	0.060	0.059	0.057	0.056
20.5	<b>0.055</b>	0.069	0.067	0.066	0.064	0.063	0.062	0.061	0.059	0.058	0.057	0.056	0.054	0.053
21.0	<b>0.053</b>	0.065	0.064	0.062	0.061	0.060	0.059	0.058	0.056	0.055	0.054	0.053	0.052	0.051
21.5	<b>0.050</b>	0.062	0.061	0.060	0.058	0.057	0.056	0.055	0.054	0.053	0.052	0.051	0.049	0.049
22.0	<b>0.048</b>	0.059	0.058	0.056	0.055	0.054	0.053	0.052	0.051	0.050	0.049	0.048	0.047	0.046
22.5	<b>0.045</b>	0.056	0.055	0.053	0.052	0.051	0.050	0.049	0.048	0.048	0.047	0.046	0.045	0.044
23.0	<b>0.043</b>	0.052	0.051	0.050	0.049	0.048	0.047	0.047	0.046	0.045	0.044	0.043	0.042	0.041
23.5	<b>0.041</b>	0.050	0.049	0.048	0.047	0.046	0.045	0.044	0.043	0.043	0.042	0.041	0.040	0.039
24.0	<b>0.039</b>	0.047	0.046	0.045	0.044	0.043	0.043	0.042	0.041	0.040	0.040	0.039	0.038	0.037
24.5	<b>0.037</b>	0.045	0.044	0.043	0.042	0.041	0.040	0.040	0.039	0.038	0.038	0.037	0.036	0.036
25.0	<b>0.035</b>	0.042	0.042	0.041	0.040	0.039	0.038	0.038	0.037	0.036	0.036	0.035	0.034	0.034
25.5	<b>0.033</b>	0.040	0.039	0.039	0.038	0.037	0.037	0.036	0.035	0.035	0.034	0.034	0.033	0.032
26.0	<b>0.032</b>	0.038	0.037	0.037	0.036	0.035	0.035	0.034	0.034	0.033	0.033	0.032	0.031	0.031
26.5	<b>0.030</b>	0.036	0.036	0.035	0.034	0.034	0.033	0.033	0.032	0.031	0.031	0.031	0.030	0.029
27.0	<b>0.029</b>	0.035	0.034	0.033	0.033	0.032	0.031	0.031	0.030	0.030	0.030	0.029	0.028	0.028

Table 12-2: C<sub>t</sub> values, Sound Optimized Mode SO2



### 12.3 Sound Curves, Sound Optimized Mode SO2

Sound Power Level at Hub Height	
Conditions for Sound Power Level:	Measurement standard IEC 61400-11 ed. 3 Maximum turbulence at hub height: 30% Inflow angle (vertical): 0 ±2° Air density: 1.225 kg/m <sup>3</sup>
Wind speed at hub height [m/s]	Sound Power Level at Hub Height [dBA] Sound Optimized Mode SO2 (Blades with serrated trailing edge)
3	90.9
4	91.1
5	92.8
6	95.9
7	99.0
8	99.4
9	99.4
10	99.5
11	99.5
12	99.5
13	99.5
14	99.4
15	99.4
16	99.5
17	99.5
18	99.5
19	99.5
20	99.5

*Table 12-3: Sound curves, Sound Optimized Mode SO2*

### 13 Power Curves, Ct Values and Sound Curves, Sound Optimized Mode SO2 (HWO)

**NOTE** The power curves and Ct values presented in Section 13 are only valid for low hub heights, i.e. hub heights ≤ 104 m.

#### 13.1 Power Curves, Sound Optimized Mode SO2 (HWO)

Wind speed [m/s]	Air density [kg/m <sup>3</sup> ]													
	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	55	31	33	35	38	40	42	44	46	48	51	53	57	59
3.5	130	89	93	97	100	104	108	111	115	119	122	126	133	137
4.0	220	159	165	170	176	182	187	193	198	204	209	215	226	231
4.5	331	246	253	261	269	277	284	292	300	308	316	324	339	347
5.0	470	352	363	374	385	395	406	417	427	438	449	459	481	491
5.5	638	483	497	511	525	539	553	568	582	596	610	624	652	666
6.0	841	640	658	676	695	713	731	749	768	786	804	822	859	877
6.5	1079	825	848	871	895	918	941	964	987	1010	1033	1056	1102	1125
7.0	1360	1042	1072	1101	1130	1159	1188	1216	1245	1274	1303	1331	1388	1417
7.5	1655	1285	1320	1356	1391	1426	1461	1496	1531	1565	1595	1625	1680	1705
8.0	1858	1537	1576	1616	1655	1694	1721	1749	1777	1805	1822	1840	1870	1882
8.5	1961	1767	1797	1827	1857	1887	1901	1915	1929	1943	1949	1955	1965	1968
9.0	2027	1940	1955	1970	1985	2000	2005	2010	2015	2020	2022	2024	2027	2028
9.5	2072	2042	2048	2054	2059	2065	2066	2068	2069	2070	2071	2071	2072	2073
10.0	2112	2105	2106	2107	2107	2108	2109	2109	2110	2111	2111	2111	2112	2112
10.5	2146	2156	2154	2152	2151	2149	2148	2148	2147	2146	2146	2146	2145	2145
11.0	2193	2228	2223	2219	2214	2210	2207	2204	2201	2199	2197	2195	2192	2190
11.5	2236	2282	2277	2271	2266	2261	2257	2253	2249	2245	2242	2239	2233	2231
12.0	2291	2341	2335	2330	2325	2319	2315	2311	2307	2302	2299	2295	2288	2285
12.5	2358	2412	2406	2400	2394	2388	2383	2378	2374	2369	2365	2361	2354	2350
13.0	2418	2473	2467	2461	2454	2448	2443	2439	2434	2429	2425	2422	2415	2411
13.5	2471	2522	2516	2510	2504	2498	2493	2489	2485	2481	2477	2474	2468	2464
14.0	2513	2564	2558	2552	2546	2540	2536	2532	2528	2523	2520	2517	2510	2508
14.5	2563	2615	2609	2604	2598	2592	2587	2583	2578	2574	2570	2567	2560	2557
15.0	2667	2712	2707	2702	2698	2693	2689	2685	2682	2678	2674	2671	2664	2660
15.5	2752	2788	2784	2781	2777	2774	2770	2767	2764	2761	2758	2755	2749	2746
16.0	2845	2872	2869	2867	2864	2862	2859	2857	2854	2852	2850	2847	2842	2840
16.5	2920	2938	2936	2935	2933	2932	2930	2929	2927	2926	2924	2922	2918	2916
17.0	2972	2975	2975	2976	2976	2976	2975	2975	2975	2974	2974	2973	2971	2970
17.5	2996	2995	2995	2995	2996	2996	2996	2996	2996	2996	2996	2996	2996	2995
18.0	3005	3004	3005	3005	3005	3005	3005	3005	3005	3005	3005	3005	3005	3005
18.5	3018	3018	3018	3018	3018	3018	3018	3018	3018	3018	3018	3018	3018	3018
19.0	3043	3054	3052	3051	3050	3049	3048	3047	3046	3045	3044	3044	3042	3041
19.5	3085	3099	3098	3097	3096	3095	3094	3092	3091	3090	3088	3087	3084	3083
20.0	3146	3156	3155	3155	3155	3155	3154	3153	3152	3151	3149	3148	3145	3143
20.5	3216	3211	3212	3213	3214	3214	3215	3216	3216	3217	3216	3216	3215	3214
21.0	3273	3257	3259	3261	3263	3265	3266	3268	3269	3270	3271	3272	3273	3274
21.5	3310	3295	3296	3298	3300	3302	3303	3304	3305	3306	3307	3308	3310	3311
22.0	3335	3319	3321	3323	3325	3327	3329	3330	3331	3333	3333	3334	3335	3336
22.5	3363	3346	3348	3350	3352	3354	3355	3357	3358	3360	3361	3362	3363	3364
23.0	3389	3368	3370	3373	3375	3377	3379	3381	3383	3385	3386	3387	3390	3391
23.5	3403	3384	3386	3388	3391	3393	3394	3396	3398	3399	3400	3402	3404	3405
24.0	3412	3394	3396	3398	3400	3402	3403	3405	3406	3408	3409	3410	3413	3414
24.5	3416	3399	3400	3402	3404	3406	3407	3409	3410	3412	3413	3414	3417	3418
25.0	3416	3398	3400	3403	3405	3407	3409	3411	3413	3414	3415	3416	3417	3418
25.5	3404	3378	3381	3384	3386	3389	3391	3394	3396	3398	3400	3402	3405	3407
26.0	3400	3378	3380	3382	3385	3387	3389	3391	3393	3395	3397	3399	3402	3403
26.5	3387	3367	3369	3371	3373	3376	3378	3380	3381	3383	3385	3386	3389	3390
27.0	3335	3320	3321	3323	3324	3326	3327	3328	3330	3331	3332	3334	3336	3337
27.5	3140	3135	3136	3136	3137	3137	3138	3138	3139	3139	3140	3140	3141	3141
28.0	2823	2821	2821	2821	2822	2822	2822	2822	2822	2822	2823	2823	2823	2824

<b>Air density [kg/m<sup>3</sup>]</b>														
<b>Wind speed [m/s]</b>	<b>1.225</b>	<b>0.950</b>	<b>0.975</b>	<b>1.000</b>	<b>1.025</b>	<b>1.050</b>	<b>1.075</b>	<b>1.100</b>	<b>1.125</b>	<b>1.150</b>	<b>1.175</b>	<b>1.200</b>	<b>1.250</b>	<b>1.275</b>
<b>28.5</b>	<b>2364</b>	2366	2366	2366	2365	2365	2365	2365	2365	2364	2364	2364	2364	2364
<b>29.0</b>	<b>1892</b>	1895	1894	1894	1894	1894	1893	1893	1893	1893	1893	1893	1892	1892
<b>29.5</b>	<b>1570</b>	1571	1571	1571	1571	1570	1570	1570	1570	1570	1570	1570	1570	1570
<b>30.0</b>	<b>1363</b>	1364	1364	1364	1364	1364	1364	1364	1364	1364	1363	1363	1363	1363
<b>30.5</b>	<b>1225</b>	1225	1225	1225	1225	1225	1225	1225	1225	1225	1225	1225	1225	1225
<b>31.0</b>	<b>1150</b>	1150	1150	1150	1150	1150	1150	1150	1150	1150	1150	1150	1150	1150
<b>31.5</b>	<b>1098</b>	1098	1098	1098	1098	1098	1098	1098	1098	1098	1098	1098	1098	1098
<b>32.0</b>	<b>1074</b>	1074	1074	1074	1074	1074	1074	1074	1074	1074	1074	1074	1074	1075

*Table 13-1: Power curve, Sound Optimized Mode SO2 (HWO)*



**13.3 Sound Curves, Sound Optimized Mode SO2 (HWO)**

Sound Power Level at Hub Height	
Conditions for Sound Power Level:	Measurement standard IEC 61400-11 ed. 3 Maximum turbulence at hub height: 30% Inflow angle (vertical): 0 ±2° Air density: 1.225 kg/m <sup>3</sup>
Wind speed at hub height [m/s]	Sound Power Level at Hub Height [dBA] Sound Optimized Mode SO2 (HWO) (Blades with serrated trailing edge)
3	90.9
4	91.1
5	92.8
6	95.9
7	99.0
8	99.4
9	99.4
10	99.5
11	99.5
12	99.5
13	99.5
14	99.4
15	99.4
16	99.5
17	99.5
18	99.5
19	99.5
20	99.5

Table 13-3: Sound curves, Sound Optimized Mode SO2 (HWO)

## 14 Power Curves, Ct Values and Sound Curves, Sound Optimized Mode SO11

**NOTE** The power curves and Ct values presented in Section 14 are only valid for low hub heights, i.e. hub heights ≤ 104 m.

### 14.1 Power Curves, Sound Optimized Mode SO11

Wind speed [m/s]	Air density [kg/m <sup>3</sup> ]													
	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	19	7	8	9	10	11	12	13	14	15	16	17	20	21
3.5	96	61	64	67	70	73	77	80	83	86	89	93	99	102
4.0	198	141	146	151	157	162	167	172	177	183	188	193	203	209
4.5	323	238	246	254	261	269	277	284	292	300	308	315	331	338
5.0	470	352	363	374	384	395	406	416	427	438	448	459	480	491
5.5	634	480	494	508	522	536	550	564	578	592	606	620	648	662
6.0	812	620	637	655	672	690	707	725	742	760	777	794	829	846
6.5	993	762	783	804	825	846	867	888	909	930	951	972	1013	1034
7.0	1176	906	930	955	980	1004	1029	1054	1078	1103	1127	1152	1200	1225
7.5	1354	1045	1073	1102	1130	1158	1186	1214	1242	1270	1298	1326	1381	1408
8.0	1527	1187	1218	1250	1282	1313	1345	1376	1407	1439	1468	1497	1553	1580
8.5	1705	1396	1428	1460	1493	1525	1553	1582	1610	1638	1660	1682	1723	1741
9.0	1894	1699	1723	1746	1770	1794	1810	1826	1843	1859	1871	1882	1902	1911
9.5	2049	1960	1973	1986	1998	2011	2017	2024	2030	2036	2041	2045	2052	2054
10.0	2152	2123	2128	2132	2137	2142	2144	2145	2147	2149	2150	2151	2153	2154
10.5	2215	2202	2204	2206	2208	2210	2211	2212	2213	2214	2214	2214	2215	2215
11.0	2264	2257	2258	2259	2260	2261	2262	2262	2263	2263	2264	2264	2264	2264
11.5	2307	2304	2305	2305	2306	2306	2307	2307	2307	2307	2307	2307	2307	2307
12.0	2342	2341	2342	2342	2342	2342	2342	2342	2342	2342	2342	2342	2342	2341
12.5	2370	2371	2371	2371	2371	2371	2371	2371	2371	2370	2370	2370	2370	2370
13.0	2396	2398	2398	2398	2398	2398	2398	2398	2398	2397	2397	2397	2396	2396
13.5	2418	2420	2420	2420	2420	2420	2420	2419	2419	2419	2419	2419	2418	2418
14.0	2434	2436	2435	2435	2435	2435	2435	2435	2435	2435	2435	2434	2434	2434
14.5	2448	2450	2450	2450	2450	2450	2450	2449	2449	2449	2449	2449	2448	2448
15.0	2463	2465	2465	2465	2464	2464	2464	2464	2464	2464	2464	2463	2463	2462
15.5	2479	2481	2481	2481	2481	2480	2480	2480	2480	2480	2479	2479	2478	2478
16.0	2496	2499	2499	2499	2498	2498	2498	2498	2497	2497	2497	2496	2496	2495
16.5	2515	2519	2518	2518	2518	2517	2517	2517	2516	2516	2516	2515	2514	2514
17.0	2537	2542	2541	2541	2541	2540	2540	2539	2539	2538	2538	2537	2536	2536
17.5	2562	2568	2568	2567	2567	2566	2566	2565	2564	2564	2563	2563	2561	2560
18.0	2594	2602	2602	2601	2600	2600	2599	2598	2597	2597	2596	2595	2593	2593
18.5	2632	2642	2641	2640	2639	2639	2638	2637	2636	2635	2634	2633	2631	2630
19.0	2671	2681	2680	2679	2679	2678	2677	2676	2675	2674	2673	2672	2670	2669
19.5	2711	2720	2720	2719	2718	2718	2717	2716	2715	2714	2713	2712	2710	2709
20.0	2745	2753	2752	2752	2751	2750	2750	2749	2748	2747	2747	2746	2744	2743
20.5	2771	2776	2775	2775	2775	2774	2774	2773	2773	2772	2772	2771	2770	2769
21.0	2788	2792	2791	2791	2790	2790	2790	2789	2789	2789	2788	2788	2787	2786
21.5	2802	2809	2808	2808	2808	2807	2806	2806	2805	2804	2803	2802	2801	2800
22.0	2830	2842	2841	2840	2839	2838	2837	2836	2834	2833	2832	2831	2829	2828
22.5	2872	2887	2886	2885	2883	2882	2881	2879	2878	2876	2875	2873	2870	2869
23.0	2909	2919	2918	2918	2917	2916	2915	2914	2914	2913	2912	2910	2908	2908
23.5	2938	2946	2946	2945	2944	2944	2943	2942	2941	2940	2940	2939	2937	2936
24.0	2962	2968	2967	2966	2966	2966	2965	2965	2964	2964	2963	2962	2961	2960
24.5	2976	2979	2979	2979	2979	2978	2978	2978	2978	2977	2977	2977	2976	2976
25.0	2983	2984	2984	2984	2984	2984	2984	2984	2983	2983	2983	2983	2983	2982
25.5	2986	2986	2986	2986	2986	2986	2986	2986	2986	2986	2986	2986	2985	2985
26.0	2986	2986	2986	2986	2986	2986	2986	2986	2986	2986	2986	2986	2986	2986
26.5	2986	2986	2986	2986	2986	2986	2986	2986	2986	2986	2986	2986	2986	2986
27.0	2986	2986	2986	2986	2986	2986	2986	2986	2986	2986	2986	2986	2986	2986

Table 14-1: Power curve, Sound Optimized Mode SO11

**14.2 Ct Values, Sound Optimized Mode SO11**

Air density kg/m <sup>3</sup>														
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	0.907	0.918	0.917	0.916	0.915	0.914	0.913	0.912	0.911	0.910	0.909	0.908	0.906	0.905
3.5	0.875	0.883	0.882	0.881	0.881	0.880	0.879	0.879	0.878	0.877	0.876	0.876	0.874	0.873
4.0	0.848	0.858	0.857	0.856	0.855	0.854	0.853	0.852	0.851	0.850	0.849	0.849	0.847	0.847
4.5	0.832	0.833	0.833	0.833	0.833	0.833	0.833	0.833	0.833	0.833	0.832	0.832	0.832	0.831
5.0	0.832	0.836	0.836	0.836	0.835	0.835	0.835	0.834	0.834	0.834	0.833	0.833	0.832	0.831
5.5	0.782	0.788	0.787	0.787	0.786	0.786	0.785	0.785	0.784	0.784	0.783	0.783	0.782	0.781
6.0	0.706	0.711	0.711	0.710	0.710	0.709	0.709	0.708	0.708	0.707	0.707	0.707	0.706	0.705
6.5	0.636	0.640	0.640	0.640	0.639	0.639	0.638	0.638	0.637	0.637	0.636	0.636	0.635	0.635
7.0	0.573	0.578	0.577	0.577	0.576	0.576	0.576	0.575	0.575	0.575	0.574	0.574	0.573	0.573
7.5	0.517	0.521	0.521	0.520	0.520	0.520	0.519	0.519	0.519	0.518	0.518	0.518	0.517	0.516
8.0	0.467	0.473	0.473	0.472	0.472	0.472	0.471	0.471	0.470	0.470	0.469	0.468	0.465	0.463
8.5	0.425	0.457	0.455	0.453	0.451	0.449	0.446	0.443	0.440	0.437	0.433	0.429	0.421	0.416
9.0	0.393	0.471	0.464	0.457	0.449	0.442	0.435	0.428	0.421	0.414	0.407	0.400	0.386	0.379
9.5	0.358	0.464	0.453	0.442	0.432	0.421	0.411	0.401	0.392	0.382	0.374	0.366	0.350	0.343
10.0	0.318	0.424	0.413	0.401	0.389	0.378	0.368	0.359	0.350	0.341	0.333	0.326	0.311	0.305
10.5	0.279	0.370	0.360	0.350	0.340	0.330	0.322	0.314	0.307	0.299	0.292	0.286	0.273	0.268
11.0	0.246	0.324	0.315	0.307	0.298	0.290	0.283	0.276	0.269	0.263	0.257	0.251	0.241	0.236
11.5	0.218	0.285	0.277	0.270	0.263	0.256	0.250	0.244	0.238	0.232	0.227	0.223	0.213	0.209
12.0	0.193	0.252	0.245	0.239	0.233	0.227	0.221	0.216	0.211	0.206	0.202	0.198	0.190	0.186
12.5	0.173	0.224	0.218	0.213	0.207	0.202	0.197	0.193	0.188	0.184	0.180	0.176	0.169	0.166
13.0	0.155	0.200	0.195	0.190	0.185	0.181	0.177	0.173	0.169	0.165	0.162	0.158	0.152	0.149
13.5	0.140	0.180	0.176	0.172	0.168	0.163	0.160	0.156	0.153	0.149	0.146	0.143	0.138	0.135
14.0	0.127	0.162	0.159	0.155	0.151	0.147	0.144	0.141	0.138	0.135	0.132	0.129	0.124	0.122
14.5	0.115	0.147	0.143	0.140	0.137	0.133	0.130	0.128	0.125	0.122	0.120	0.117	0.113	0.111
15.0	0.104	0.133	0.130	0.127	0.124	0.121	0.118	0.116	0.113	0.111	0.108	0.106	0.102	0.100
15.5	0.095	0.121	0.118	0.116	0.113	0.110	0.108	0.106	0.103	0.101	0.099	0.097	0.094	0.092
16.0	0.088	0.111	0.109	0.106	0.104	0.101	0.099	0.097	0.095	0.093	0.091	0.089	0.086	0.085
16.5	0.081	0.102	0.100	0.098	0.095	0.093	0.091	0.089	0.087	0.086	0.084	0.082	0.079	0.078
17.0	0.075	0.095	0.093	0.090	0.088	0.086	0.084	0.083	0.081	0.079	0.078	0.076	0.074	0.072
17.5	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	0.067
18.0	0.065	0.082	0.080	0.078	0.077	0.075	0.073	0.072	0.070	0.069	0.068	0.066	0.064	0.063
18.5	0.061	0.077	0.075	0.074	0.072	0.070	0.069	0.068	0.066	0.065	0.064	0.062	0.060	0.059
19.0	0.058	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
19.5	0.054	0.068	0.066	0.065	0.063	0.062	0.061	0.060	0.059	0.057	0.056	0.055	0.053	0.053
20.0	0.051	0.064	0.063	0.061	0.060	0.059	0.057	0.056	0.055	0.054	0.053	0.052	0.051	0.050
20.5	0.049	0.060	0.059	0.058	0.056	0.055	0.054	0.053	0.052	0.051	0.050	0.049	0.048	0.047
21.0	0.046	0.057	0.055	0.054	0.053	0.052	0.051	0.050	0.049	0.048	0.047	0.047	0.045	0.044
21.5	0.044	0.054	0.053	0.052	0.051	0.049	0.049	0.048	0.047	0.046	0.045	0.044	0.043	0.042
22.0	0.041	0.051	0.050	0.049	0.048	0.047	0.046	0.045	0.044	0.044	0.043	0.042	0.041	0.040
22.5	0.040	0.049	0.048	0.047	0.046	0.045	0.044	0.043	0.042	0.042	0.041	0.040	0.039	0.038
23.0	0.038	0.046	0.045	0.044	0.043	0.043	0.042	0.041	0.040	0.040	0.039	0.038	0.037	0.037
23.5	0.036	0.044	0.043	0.042	0.041	0.041	0.040	0.039	0.038	0.038	0.037	0.037	0.035	0.035
24.0	0.034	0.042	0.041	0.040	0.040	0.039	0.038	0.037	0.037	0.036	0.035	0.035	0.034	0.033
24.5	0.033	0.040	0.039	0.038	0.038	0.037	0.036	0.036	0.035	0.034	0.034	0.033	0.032	0.032
25.0	0.031	0.038	0.037	0.036	0.036	0.035	0.034	0.034	0.033	0.033	0.032	0.032	0.031	0.030
25.5	0.030	0.036	0.036	0.035	0.034	0.034	0.033	0.032	0.032	0.031	0.031	0.030	0.030	0.029
26.0	0.029	0.034	0.034	0.033	0.033	0.032	0.031	0.031	0.030	0.030	0.029	0.029	0.028	0.028
26.5	0.027	0.033	0.032	0.032	0.031	0.030	0.030	0.029	0.029	0.029	0.028	0.028	0.027	0.027
27.0	0.026	0.031	0.031	0.030	0.030	0.029	0.029	0.028	0.028	0.027	0.027	0.027	0.026	0.025

Table 14-2: C<sub>t</sub> values, Sound Optimized Mode SO11

### 14.3 Sound Curves, Sound Optimized Mode SO11

Sound Power Level at Hub Height	
Conditions for Sound Power Level:	Measurement standard IEC 61400-11 ed. 3 Maximum turbulence at hub height: 30% Inflow angle (vertical): 0 ±2° Air density: 1.225 kg/m <sup>3</sup>
Wind speed at hub height [m/s]	Sound Power Level at Hub Height [dBA] Sound Optimized Mode SO11 (Blades with serrated trailing edge)
3	92.1
4	92.4
5	92.9
6	94.5
7	95.5
8	96.8
9	98.0
10	98.8
11	99.0
12	99.2
13	99.2
14	99.2
15	99.2
16	99.2
17	99.2
18	99.2
19	99.2
20	99.2

*Table 14-3: Sound curves, Sound Optimized Mode SO11*



**15 Power Curves, Ct Values and Sound Curves, Sound Optimized Mode SO11 (HWO)**

**NOTE** The power curves and Ct values presented in Section 15 are only valid for low hub heights, i.e. hub heights ≤ 104 m.

**15.1 Power Curves, Sound Optimized Mode SO11 (HWO)**

Air density [kg/m <sup>3</sup> ]														
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	19	7	8	9	10	11	12	13	14	15	16	17	20	21
3.5	96	61	64	67	70	73	77	80	83	86	89	93	99	102
4.0	198	141	146	151	157	162	167	172	177	183	188	193	203	209
4.5	323	238	246	254	261	269	277	284	292	300	308	315	331	338
5.0	470	352	363	374	384	395	406	416	427	438	448	459	480	491
5.5	634	480	494	508	522	536	550	564	578	592	606	620	648	662
6.0	812	620	637	655	672	690	707	725	742	760	777	794	829	846
6.5	993	762	783	804	825	846	867	888	909	930	951	972	1013	1034
7.0	1176	906	930	955	980	1004	1029	1054	1078	1103	1127	1152	1200	1225
7.5	1354	1045	1073	1102	1130	1158	1186	1214	1242	1270	1298	1326	1381	1408
8.0	1527	1187	1218	1250	1282	1313	1345	1376	1407	1439	1468	1497	1553	1580
8.5	1705	1396	1428	1460	1493	1525	1553	1582	1610	1638	1660	1682	1723	1741
9.0	1894	1699	1723	1746	1770	1794	1810	1826	1843	1859	1871	1882	1902	1911
9.5	2049	1960	1973	1986	1998	2011	2017	2024	2030	2036	2041	2045	2052	2054
10.0	2152	2123	2128	2132	2137	2142	2144	2145	2147	2149	2150	2151	2153	2154
10.5	2215	2202	2204	2206	2208	2210	2211	2212	2213	2214	2214	2214	2215	2215
11.0	2264	2257	2258	2259	2260	2261	2262	2262	2263	2263	2264	2264	2264	2264
11.5	2307	2304	2305	2305	2306	2306	2307	2307	2307	2307	2307	2307	2307	2307
12.0	2342	2341	2342	2342	2342	2342	2342	2342	2342	2342	2342	2342	2342	2341
12.5	2370	2371	2371	2371	2371	2371	2371	2371	2371	2370	2370	2370	2370	2370
13.0	2396	2398	2398	2398	2398	2398	2398	2398	2398	2397	2397	2397	2396	2396
13.5	2418	2420	2420	2420	2420	2420	2420	2419	2419	2419	2419	2419	2418	2418
14.0	2434	2436	2435	2435	2435	2435	2435	2435	2435	2435	2435	2434	2434	2434
14.5	2448	2450	2450	2450	2450	2450	2450	2449	2449	2449	2449	2449	2448	2448
15.0	2463	2465	2465	2465	2464	2464	2464	2464	2464	2464	2464	2463	2463	2462
15.5	2479	2481	2481	2481	2481	2480	2480	2480	2480	2480	2479	2479	2478	2478
16.0	2496	2499	2499	2499	2498	2498	2498	2498	2497	2497	2497	2496	2496	2495
16.5	2515	2519	2518	2518	2518	2517	2517	2517	2516	2516	2516	2515	2514	2514
17.0	2537	2542	2541	2541	2541	2540	2540	2539	2539	2538	2538	2537	2536	2536
17.5	2562	2568	2568	2567	2567	2566	2566	2565	2564	2564	2563	2563	2561	2560
18.0	2594	2602	2602	2601	2600	2600	2599	2598	2597	2597	2596	2595	2593	2593
18.5	2632	2642	2641	2640	2639	2639	2638	2637	2636	2635	2634	2633	2631	2630
19.0	2671	2681	2680	2679	2679	2678	2677	2676	2675	2674	2673	2672	2670	2669
19.5	2711	2720	2720	2719	2718	2718	2717	2716	2715	2714	2713	2712	2710	2709
20.0	2745	2753	2752	2752	2751	2750	2750	2749	2748	2747	2747	2746	2744	2743
20.5	2771	2776	2775	2775	2775	2774	2774	2773	2773	2772	2772	2771	2770	2769
21.0	2788	2792	2791	2791	2790	2790	2790	2789	2789	2789	2788	2788	2787	2786
21.5	2802	2809	2808	2808	2808	2807	2806	2806	2805	2804	2803	2802	2801	2800
22.0	2830	2842	2841	2840	2839	2838	2837	2836	2834	2833	2832	2831	2829	2828
22.5	2872	2887	2886	2885	2883	2882	2881	2879	2878	2876	2875	2873	2870	2869
23.0	2909	2919	2918	2918	2917	2916	2915	2914	2914	2913	2912	2910	2908	2908
23.5	2938	2946	2946	2945	2944	2944	2943	2942	2941	2940	2940	2939	2937	2936
24.0	2962	2968	2967	2966	2966	2966	2965	2965	2964	2964	2963	2962	2961	2960
24.5	2976	2979	2979	2979	2979	2978	2978	2978	2978	2977	2977	2977	2976	2976
25.0	2983	2984	2984	2984	2984	2984	2984	2984	2983	2983	2983	2983	2983	2982
25.5	2986	2986	2986	2986	2986	2986	2986	2986	2986	2986	2986	2986	2985	2985
26.0	2986	2986	2986	2986	2986	2986	2986	2986	2986	2986	2986	2986	2986	2986
26.5	2986	2986	2986	2986	2986	2986	2986	2986	2986	2986	2986	2986	2986	2986
27.0	2986	2986	2986	2986	2986	2986	2986	2986	2986	2986	2986	2986	2986	2986
27.5	2986	2986	2986	2986	2986	2986	2986	2986	2986	2986	2986	2986	2986	2986
28.0	2983	2983	2983	2983	2983	2984	2984	2984	2984	2984	2983	2983	2983	2983

<b>Air density [kg/m<sup>3</sup>]</b>														
<b>Wind speed [m/s]</b>	<b>1.225</b>	<b>0.950</b>	<b>0.975</b>	<b>1.000</b>	<b>1.025</b>	<b>1.050</b>	<b>1.075</b>	<b>1.100</b>	<b>1.125</b>	<b>1.150</b>	<b>1.175</b>	<b>1.200</b>	<b>1.250</b>	<b>1.275</b>
<b>28.5</b>	<b>2956</b>	2956	2956	2956	2956	2956	2956	2956	2956	2956	2956	2956	2956	2956
<b>29.0</b>	<b>2880</b>	2880	2880	2880	2880	2880	2880	2880	2880	2880	2880	2880	2880	2880
<b>29.5</b>	<b>2737</b>	2737	2737	2737	2737	2737	2737	2737	2737	2737	2737	2737	2737	2737
<b>30.0</b>	<b>2536</b>	2536	2536	2536	2536	2536	2536	2536	2536	2536	2536	2536	2536	2536
<b>30.5</b>	<b>2306</b>	2306	2306	2306	2306	2306	2306	2306	2306	2306	2306	2306	2306	2306
<b>31.0</b>	<b>2072</b>	2073	2073	2073	2073	2073	2073	2073	2073	2073	2073	2073	2073	2072
<b>31.5</b>	<b>1868</b>	1868	1868	1868	1868	1868	1868	1868	1868	1868	1868	1868	1868	1868
<b>32.0</b>	<b>1721</b>	1721	1721	1721	1721	1721	1721	1721	1721	1721	1721	1721	1721	1721

*Table 15-1: Power curve, Sound Optimized Mode SO11 (HWO)*



**15.3 Sound Curves, Sound Optimized Mode SO11 (HWO)**

<b>Sound Power Level at Hub Height</b>	
<b>Conditions for Sound Power Level:</b>	Measurement standard IEC 61400-11 ed. 3 Maximum turbulence at hub height: 30% Inflow angle (vertical): 0 ±2° Air density: 1.225 kg/m <sup>3</sup>
<b>Wind speed at hub height [m/s]</b>	<b>Sound Power Level at Hub Height [dBA] Sound Optimized Mode SO11 (HWO) (Blades with serrated trailing edge)</b>
3	92.1
4	92.4
5	92.9
6	94.5
7	95.5
8	96.8
9	98.0
10	98.8
11	99.0
12	99.2
13	99.2
14	99.2
15	99.2
16	99.2
17	99.2
18	99.2
19	99.2
20	99.2

*Table 15-3: Sound curves, Sound Optimized Mode SO11 (HWO)*

**16 Power Curves, Ct Values and Sound Curves, Sound Optimized Mode SO12**

**NOTE** The power curves and Ct values presented in Section 16 are only valid for low hub heights, i.e. hub heights ≤ 104 m.

**16.1 Power Curves, Sound Optimized Mode SO12**

Wind speed [m/s]	Air density [kg/m <sup>3</sup> ]													
	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	19	7	8	9	10	11	12	13	14	15	16	17	20	21
3.5	96	61	64	67	70	73	77	80	83	86	89	93	99	102
4.0	198	141	146	151	157	162	167	172	177	183	188	193	203	209
4.5	323	238	246	254	261	269	277	284	292	300	308	315	331	338
5.0	470	352	363	374	384	395	406	416	427	438	448	459	480	491
5.5	637	483	497	511	525	539	553	567	581	595	609	623	651	665
6.0	830	633	651	669	687	705	723	741	759	777	794	812	848	865
6.5	1037	796	818	840	862	884	906	928	950	972	994	1016	1059	1081
7.0	1244	958	984	1010	1036	1063	1089	1115	1141	1167	1192	1218	1270	1295
7.5	1414	1092	1121	1151	1180	1210	1239	1269	1298	1327	1356	1385	1444	1472
8.0	1573	1218	1250	1283	1315	1348	1380	1412	1445	1477	1509	1541	1605	1636
8.5	1805	1434	1469	1505	1541	1576	1610	1644	1677	1711	1742	1774	1835	1865
9.0	2100	1817	1848	1880	1911	1942	1967	1991	2015	2040	2060	2080	2118	2136
9.5	2301	2145	2167	2190	2212	2234	2246	2257	2269	2280	2287	2294	2307	2312
10.0	2382	2331	2341	2350	2360	2370	2373	2375	2377	2379	2380	2381	2383	2383
10.5	2422	2407	2409	2412	2415	2417	2418	2419	2420	2421	2421	2422	2423	2423
11.0	2458	2450	2452	2453	2454	2455	2456	2456	2457	2457	2458	2458	2458	2458
11.5	2486	2483	2483	2484	2484	2485	2485	2485	2486	2486	2486	2486	2486	2486
12.0	2510	2509	2509	2509	2509	2510	2510	2510	2510	2510	2510	2510	2509	2509
12.5	2534	2535	2535	2535	2535	2535	2535	2535	2535	2534	2534	2534	2534	2533
13.0	2567	2570	2570	2570	2570	2570	2570	2569	2569	2568	2568	2568	2567	2566
13.5	2621	2626	2625	2625	2625	2625	2624	2624	2623	2623	2622	2621	2620	2619
14.0	2679	2685	2684	2684	2684	2684	2683	2682	2682	2681	2680	2680	2678	2677
14.5	2740	2746	2746	2746	2745	2745	2744	2744	2743	2742	2741	2741	2739	2738
15.0	2803	2810	2810	2809	2809	2808	2808	2807	2806	2805	2804	2804	2802	2800
15.5	2863	2872	2871	2871	2870	2870	2869	2868	2867	2866	2865	2864	2862	2861
16.0	2922	2931	2931	2930	2930	2929	2928	2927	2927	2926	2925	2924	2921	2920
16.5	2978	2987	2986	2986	2986	2985	2984	2983	2982	2981	2980	2979	2977	2976
17.0	3030	3040	3039	3038	3038	3037	3036	3035	3035	3034	3033	3032	3029	3028
17.5	3081	3090	3090	3089	3088	3088	3087	3086	3085	3084	3083	3082	3080	3078
18.0	3131	3141	3141	3140	3139	3138	3137	3136	3135	3134	3133	3132	3129	3128
18.5	3182	3194	3193	3192	3192	3191	3190	3189	3187	3186	3185	3184	3181	3180
19.0	3236	3249	3248	3247	3246	3245	3244	3243	3241	3240	3239	3238	3235	3234
19.5	3290	3302	3301	3300	3299	3298	3297	3296	3295	3294	3292	3291	3288	3286
20.0	3339	3351	3350	3349	3348	3348	3346	3345	3344	3343	3342	3340	3338	3336
20.5	3384	3396	3395	3394	3393	3392	3391	3390	3389	3388	3387	3386	3383	3382
21.0	3428	3439	3438	3437	3436	3436	3435	3433	3432	3431	3430	3429	3426	3425
21.5	3470	3481	3480	3479	3478	3478	3476	3475	3474	3473	3472	3471	3468	3467
22.0	3510	3522	3521	3520	3519	3518	3517	3516	3515	3514	3513	3512	3509	3508
22.5	3547	3557	3556	3555	3554	3553	3553	3552	3551	3550	3549	3548	3546	3544
23.0	3574	3582	3582	3581	3581	3580	3579	3579	3578	3577	3576	3575	3574	3573
23.5	3598	3603	3603	3602	3602	3602	3601	3601	3600	3599	3599	3598	3597	3596
24.0	3614	3618	3618	3617	3617	3616	3616	3616	3615	3615	3615	3614	3613	3613
24.5	3624	3626	3626	3626	3626	3626	3625	3625	3625	3625	3625	3624	3624	3624
25.0	3630	3632	3632	3631	3631	3631	3631	3631	3631	3631	3630	3630	3630	3630
25.5	3634	3634	3634	3634	3634	3634	3634	3634	3634	3634	3634	3634	3634	3634
26.0	3635	3635	3635	3635	3635	3635	3635	3635	3635	3635	3635	3635	3635	3635
26.5	3636	3636	3636	3636	3636	3636	3636	3636	3636	3636	3636	3636	3636	3636
27.0	3636	3636	3636	3636	3636	3636	3636	3636	3636	3636	3636	3636	3635	3635

Table 16-1: Power curve, Sound Optimized Mode SO12

**16.2 Ct Values, Sound Optimized Mode SO12**

Air density kg/m <sup>3</sup>														
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	0.907	0.918	0.917	0.916	0.915	0.914	0.913	0.912	0.911	0.910	0.909	0.908	0.906	0.905
3.5	0.875	0.883	0.882	0.881	0.881	0.880	0.879	0.879	0.878	0.877	0.876	0.876	0.874	0.873
4.0	0.848	0.858	0.857	0.856	0.855	0.854	0.853	0.852	0.851	0.850	0.849	0.849	0.847	0.847
4.5	0.832	0.833	0.833	0.833	0.833	0.833	0.833	0.833	0.833	0.833	0.832	0.832	0.832	0.831
5.0	0.836	0.840	0.840	0.839	0.839	0.839	0.838	0.838	0.838	0.837	0.837	0.837	0.836	0.835
5.5	0.804	0.809	0.809	0.808	0.808	0.807	0.807	0.806	0.806	0.805	0.805	0.804	0.803	0.803
6.0	0.749	0.755	0.755	0.754	0.754	0.753	0.752	0.752	0.751	0.751	0.750	0.750	0.749	0.748
6.5	0.694	0.700	0.700	0.699	0.699	0.698	0.697	0.697	0.696	0.696	0.695	0.695	0.694	0.693
7.0	0.632	0.637	0.637	0.636	0.636	0.635	0.635	0.634	0.634	0.633	0.633	0.632	0.631	0.631
7.5	0.557	0.561	0.561	0.560	0.560	0.559	0.559	0.559	0.558	0.558	0.557	0.557	0.556	0.556
8.0	0.491	0.495	0.495	0.495	0.494	0.494	0.493	0.493	0.492	0.492	0.491	0.491	0.490	0.490
8.5	0.459	0.477	0.476	0.474	0.473	0.472	0.470	0.468	0.466	0.465	0.463	0.461	0.457	0.454
9.0	0.446	0.521	0.514	0.507	0.499	0.492	0.485	0.479	0.472	0.465	0.459	0.452	0.440	0.434
9.5	0.412	0.529	0.518	0.506	0.494	0.483	0.472	0.462	0.451	0.440	0.431	0.421	0.404	0.395
10.0	0.358	0.484	0.471	0.457	0.443	0.430	0.419	0.408	0.396	0.385	0.376	0.367	0.350	0.343
10.5	0.309	0.415	0.403	0.391	0.379	0.367	0.358	0.349	0.340	0.331	0.324	0.316	0.302	0.296
11.0	0.269	0.357	0.347	0.337	0.328	0.318	0.310	0.303	0.295	0.288	0.282	0.275	0.264	0.258
11.5	0.236	0.310	0.302	0.294	0.286	0.278	0.271	0.265	0.258	0.252	0.247	0.241	0.231	0.226
12.0	0.208	0.272	0.265	0.258	0.251	0.244	0.239	0.233	0.228	0.222	0.217	0.213	0.204	0.200
12.5	0.185	0.240	0.234	0.228	0.222	0.216	0.212	0.207	0.202	0.197	0.193	0.189	0.182	0.178
13.0	0.166	0.215	0.210	0.205	0.199	0.194	0.190	0.186	0.181	0.177	0.173	0.170	0.163	0.160
13.5	0.152	0.196	0.192	0.187	0.182	0.177	0.173	0.170	0.166	0.162	0.159	0.155	0.149	0.146
14.0	0.139	0.179	0.175	0.171	0.166	0.162	0.159	0.155	0.152	0.148	0.145	0.142	0.137	0.134
14.5	0.128	0.165	0.161	0.157	0.153	0.149	0.146	0.143	0.139	0.136	0.134	0.131	0.126	0.123
15.0	0.118	0.151	0.148	0.144	0.141	0.137	0.134	0.131	0.128	0.125	0.123	0.120	0.116	0.114
15.5	0.109	0.140	0.137	0.133	0.130	0.127	0.124	0.122	0.119	0.116	0.114	0.112	0.107	0.105
16.0	0.102	0.130	0.127	0.124	0.121	0.118	0.115	0.113	0.110	0.108	0.106	0.104	0.100	0.098
16.5	0.095	0.121	0.118	0.115	0.112	0.110	0.107	0.105	0.103	0.101	0.099	0.097	0.093	0.091
17.0	0.088	0.113	0.110	0.107	0.105	0.102	0.100	0.098	0.096	0.094	0.092	0.090	0.087	0.085
17.5	0.083	0.105	0.103	0.100	0.098	0.095	0.093	0.091	0.089	0.088	0.086	0.084	0.081	0.080
18.0	0.077	0.098	0.096	0.094	0.092	0.089	0.087	0.086	0.084	0.082	0.081	0.079	0.076	0.075
18.5	0.073	0.092	0.090	0.088	0.086	0.084	0.082	0.081	0.079	0.077	0.076	0.074	0.072	0.070
19.0	0.068	0.086	0.084	0.082	0.081	0.079	0.077	0.075	0.074	0.072	0.071	0.070	0.067	0.066
19.5	0.065	0.081	0.080	0.078	0.076	0.074	0.073	0.071	0.070	0.068	0.067	0.066	0.063	0.062
20.0	0.061	0.077	0.075	0.073	0.072	0.070	0.069	0.067	0.066	0.065	0.063	0.062	0.060	0.059
20.5	0.058	0.073	0.071	0.069	0.068	0.066	0.065	0.064	0.062	0.061	0.060	0.059	0.057	0.056
21.0	0.055	0.069	0.067	0.066	0.064	0.063	0.062	0.060	0.059	0.058	0.057	0.056	0.054	0.053
21.5	0.053	0.066	0.064	0.063	0.061	0.060	0.059	0.058	0.057	0.055	0.054	0.053	0.052	0.051
22.0	0.050	0.062	0.061	0.060	0.058	0.057	0.056	0.055	0.054	0.053	0.052	0.051	0.049	0.048
22.5	0.047	0.059	0.058	0.057	0.055	0.054	0.053	0.052	0.051	0.050	0.049	0.048	0.047	0.046
23.0	0.045	0.056	0.054	0.053	0.052	0.051	0.050	0.049	0.048	0.047	0.046	0.046	0.044	0.043
23.5	0.043	0.053	0.052	0.051	0.049	0.048	0.048	0.047	0.046	0.045	0.044	0.043	0.042	0.041
24.0	0.041	0.050	0.049	0.048	0.047	0.046	0.045	0.044	0.043	0.043	0.042	0.041	0.040	0.039
24.5	0.039	0.047	0.046	0.046	0.045	0.044	0.043	0.042	0.041	0.041	0.040	0.039	0.038	0.037
25.0	0.037	0.045	0.044	0.043	0.042	0.041	0.041	0.040	0.039	0.039	0.038	0.037	0.036	0.036
25.5	0.035	0.043	0.042	0.041	0.040	0.040	0.039	0.038	0.038	0.037	0.036	0.036	0.035	0.034
26.0	0.034	0.041	0.040	0.039	0.038	0.038	0.037	0.036	0.036	0.035	0.035	0.034	0.033	0.033
26.5	0.032	0.039	0.038	0.037	0.037	0.036	0.035	0.035	0.034	0.033	0.033	0.032	0.032	0.031
27.0	0.031	0.037	0.036	0.036	0.035	0.034	0.034	0.033	0.033	0.032	0.032	0.031	0.030	0.030

Table 16-2: C<sub>t</sub> values, Sound Optimized Mode SO12

**16.3 Sound Curves, Sound Optimized Mode SO12**

<b>Sound Power Level at Hub Height</b>	
<b>Conditions for Sound Power Level:</b>	Measurement standard IEC 61400-11 ed. 3 Maximum turbulence at hub height: 30% Inflow angle (vertical): 0 ±2° Air density: 1.225 kg/m <sup>3</sup>
<b>Wind speed at hub height [m/s]</b>	<b>Sound Power Level at Hub Height [dBA] Sound Optimized Mode SO12 (Blades with serrated trailing edge)</b>
3	92.1
4	92.4
5	93.0
6	94.9
7	97.1
8	98.8
9	99.7
10	99.9
11	99.9
12	99.9
13	99.9
14	99.9
15	99.9
16	99.9
17	99.9
18	99.9
19	99.9
20	99.9

*Table 16-3: Sound curves, Sound Optimized Mode SO12*

## 17 Power Curves, Ct Values and Sound Curves, Sound Optimized Mode SO12 (HWO)

**NOTE** The power curves and Ct values presented in Section 17 are only valid for low hub heights, i.e. hub heights ≤ 104 m.

### 17.1 Power Curves, Sound Optimized Mode SO12 (HWO)

Wind speed [m/s]	Air density [kg/m <sup>3</sup> ]													
	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	19	7	8	9	10	11	12	13	14	15	16	17	20	21
3.5	96	61	64	67	70	73	77	80	83	86	89	93	99	102
4.0	198	141	146	151	157	162	167	172	177	183	188	193	203	209
4.5	323	238	246	254	261	269	277	284	292	300	308	315	331	338
5.0	470	352	363	374	384	395	406	416	427	438	448	459	480	491
5.5	637	483	497	511	525	539	553	567	581	595	609	623	651	665
6.0	830	633	651	669	687	705	723	741	759	777	794	812	848	865
6.5	1037	796	818	840	862	884	906	928	950	972	994	1016	1059	1081
7.0	1244	958	984	1010	1036	1063	1089	1115	1141	1167	1192	1218	1270	1295
7.5	1414	1092	1121	1151	1180	1210	1239	1269	1298	1327	1356	1385	1444	1472
8.0	1573	1218	1250	1283	1315	1348	1380	1412	1445	1477	1509	1541	1605	1636
8.5	1805	1434	1469	1505	1541	1576	1610	1644	1677	1711	1742	1774	1835	1865
9.0	2100	1817	1848	1880	1911	1942	1967	1991	2015	2040	2060	2080	2118	2136
9.5	2301	2145	2167	2190	2212	2234	2246	2257	2269	2280	2287	2294	2307	2312
10.0	2382	2331	2341	2350	2360	2370	2373	2375	2377	2379	2380	2381	2383	2383
10.5	2422	2407	2409	2412	2415	2417	2418	2419	2420	2421	2421	2422	2423	2423
11.0	2458	2450	2452	2453	2454	2455	2456	2456	2457	2457	2458	2458	2458	2458
11.5	2486	2483	2483	2484	2484	2485	2485	2485	2486	2486	2486	2486	2486	2486
12.0	2510	2509	2509	2509	2509	2510	2510	2510	2510	2510	2510	2510	2509	2509
12.5	2534	2535	2535	2535	2535	2535	2535	2535	2535	2534	2534	2534	2534	2533
13.0	2567	2570	2570	2570	2570	2570	2570	2569	2569	2568	2568	2568	2567	2566
13.5	2621	2626	2625	2625	2625	2625	2624	2624	2623	2623	2622	2621	2620	2619
14.0	2679	2685	2684	2684	2684	2684	2683	2682	2682	2681	2680	2680	2678	2677
14.5	2740	2746	2746	2746	2745	2745	2744	2744	2743	2742	2741	2741	2739	2738
15.0	2803	2810	2810	2809	2809	2808	2808	2807	2806	2805	2804	2804	2802	2800
15.5	2863	2872	2871	2871	2870	2870	2869	2868	2867	2866	2865	2864	2862	2861
16.0	2922	2931	2931	2930	2930	2929	2928	2927	2927	2926	2925	2924	2921	2920
16.5	2978	2987	2986	2986	2986	2985	2984	2983	2982	2981	2980	2979	2977	2976
17.0	3030	3040	3039	3038	3038	3037	3036	3035	3035	3034	3033	3032	3029	3028
17.5	3081	3090	3090	3089	3088	3088	3087	3086	3085	3084	3083	3082	3080	3078
18.0	3131	3141	3141	3140	3139	3138	3137	3136	3135	3134	3133	3132	3129	3128
18.5	3182	3194	3193	3192	3192	3191	3190	3189	3187	3186	3185	3184	3181	3180
19.0	3236	3249	3248	3247	3246	3245	3244	3243	3241	3240	3239	3238	3235	3234
19.5	3290	3302	3301	3300	3299	3298	3297	3296	3295	3294	3292	3291	3288	3286
20.0	3339	3351	3350	3349	3348	3348	3346	3345	3344	3343	3342	3340	3338	3336
20.5	3384	3396	3395	3394	3393	3392	3391	3390	3389	3388	3387	3386	3383	3382
21.0	3428	3439	3438	3437	3436	3436	3435	3433	3432	3431	3430	3429	3426	3425
21.5	3470	3481	3480	3479	3478	3478	3476	3475	3474	3473	3472	3471	3468	3467
22.0	3510	3522	3521	3520	3519	3518	3517	3516	3515	3514	3513	3512	3509	3508
22.5	3547	3557	3556	3555	3554	3553	3552	3552	3551	3550	3549	3548	3546	3544
23.0	3574	3582	3582	3581	3581	3580	3579	3579	3578	3577	3576	3575	3574	3573
23.5	3598	3603	3603	3602	3602	3602	3601	3601	3600	3599	3599	3598	3597	3596
24.0	3614	3618	3618	3617	3617	3616	3616	3616	3615	3615	3615	3614	3613	3613
24.5	3624	3626	3626	3626	3626	3626	3625	3625	3625	3625	3625	3624	3624	3624
25.0	3630	3632	3632	3631	3631	3631	3631	3631	3631	3631	3630	3630	3630	3630
25.5	3634	3634	3634	3634	3634	3634	3634	3634	3634	3634	3634	3634	3634	3634
26.0	3634	3634	3634	3634	3634	3634	3634	3634	3634	3634	3634	3634	3634	3634
26.5	3628	3628	3628	3628	3628	3628	3628	3628	3628	3628	3628	3628	3628	3628
27.0	3617	3617	3617	3617	3617	3617	3617	3617	3617	3617	3617	3617	3617	3617
27.5	3558	3558	3558	3558	3558	3558	3558	3558	3558	3558	3558	3558	3558	3558
28.0	3440	3440	3440	3440	3440	3440	3440	3440	3440	3440	3440	3440	3440	3440



<b>Air density [kg/m<sup>3</sup>]</b>														
<b>Wind speed [m/s]</b>	<b>1.225</b>	<b>0.950</b>	<b>0.975</b>	<b>1.000</b>	<b>1.025</b>	<b>1.050</b>	<b>1.075</b>	<b>1.100</b>	<b>1.125</b>	<b>1.150</b>	<b>1.175</b>	<b>1.200</b>	<b>1.250</b>	<b>1.275</b>
<b>28.5</b>	<b>3258</b>	3258	3258	3258	3258	3258	3258	3258	3258	3258	3258	3258	3258	3258
<b>29.0</b>	<b>3033</b>	3033	3033	3033	3033	3033	3033	3033	3033	3033	3033	3033	3033	3033
<b>29.5</b>	<b>2789</b>	2789	2789	2789	2789	2789	2789	2789	2789	2789	2789	2789	2789	2789
<b>30.0</b>	<b>2548</b>	2548	2548	2548	2548	2548	2548	2548	2548	2548	2548	2548	2548	2548
<b>30.5</b>	<b>2308</b>	2308	2308	2308	2308	2308	2308	2308	2308	2308	2308	2308	2308	2308
<b>31.0</b>	<b>2072</b>	2073	2073	2073	2073	2073	2073	2073	2073	2073	2073	2073	2073	2072
<b>31.5</b>	<b>1868</b>	1868	1868	1868	1868	1868	1868	1868	1868	1868	1868	1868	1868	1868
<b>32.0</b>	<b>1721</b>	1721	1721	1721	1721	1721	1721	1721	1721	1721	1721	1721	1721	1721

*Table 17-1: Power curve, Sound Optimized Mode SO12 (HWO)*



**17.3 Sound Curves, Sound Optimized Mode SO12 (HWO)**

<b>Sound Power Level at Hub Height</b>	
<b>Conditions for Sound Power Level:</b>	Measurement standard IEC 61400-11 ed. 3 Maximum turbulence at hub height: 30% Inflow angle (vertical): 0 ±2° Air density: 1.225 kg/m <sup>3</sup>
<b>Wind speed at hub height [m/s]</b>	<b>Sound Power Level at Hub Height [dBA] Sound Optimized Mode SO12 (HWO) (Blades with serrated trailing edge)</b>
3	92.1
4	92.4
5	93.0
6	94.9
7	97.1
8	98.8
9	99.7
10	99.9
11	99.9
12	99.9
13	99.9
14	99.9
15	99.9
16	99.9
17	99.9
18	99.9
19	99.9
20	99.9

*Table 17-3: Sound curves, Sound Optimized Mode SO12 (HWO)*

## 18 Power Curves, Ct Values and Sound Curves, Sound Optimized Mode SO13

**NOTE** The power curves and Ct values presented in Section 18 are only valid for low hub heights, i.e. hub heights ≤ 104 m.

### 18.1 Power Curves, Sound Optimized Mode SO13

Wind speed [m/s]	Air density [kg/m <sup>3</sup> ]													
	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	19	7	8	9	10	11	12	13	14	15	16	17	20	21
3.5	96	61	64	67	70	73	77	80	83	86	89	93	99	102
4.0	198	141	146	151	156	162	167	172	177	182	188	193	203	208
4.5	317	234	242	249	257	264	272	280	287	295	302	310	325	332
5.0	438	329	339	349	359	369	379	389	399	409	418	428	448	458
5.5	537	406	418	430	442	453	465	477	489	501	513	525	548	560
6.0	641	488	502	516	530	544	558	572	586	600	613	627	655	668
6.5	768	588	605	621	637	654	670	687	703	719	736	752	784	800
7.0	901	692	711	730	749	768	787	806	825	844	863	882	920	939
7.5	1032	795	816	838	860	881	903	924	946	968	989	1010	1053	1075
8.0	1191	923	947	972	997	1022	1046	1071	1096	1120	1144	1168	1213	1235
8.5	1353	1057	1086	1114	1143	1171	1199	1226	1253	1281	1305	1329	1374	1395
9.0	1457	1153	1184	1215	1246	1276	1305	1333	1361	1390	1412	1435	1476	1496
9.5	1532	1264	1294	1324	1354	1384	1408	1432	1455	1479	1497	1514	1545	1559
10.0	1634	1437	1461	1486	1510	1534	1551	1568	1584	1601	1612	1623	1642	1650
10.5	1739	1634	1649	1663	1677	1692	1700	1708	1716	1724	1729	1734	1742	1745
11.0	1809	1776	1782	1787	1793	1798	1800	1802	1805	1807	1807	1808	1809	1809
11.5	1841	1839	1840	1840	1840	1841	1841	1841	1841	1841	1841	1841	1841	1841
12.0	1863	1863	1863	1863	1863	1863	1863	1863	1863	1863	1863	1863	1863	1863
12.5	1882	1883	1883	1882	1882	1882	1882	1882	1882	1882	1882	1882	1882	1881
13.0	1900	1902	1901	1901	1901	1901	1901	1901	1901	1901	1901	1901	1900	1900
13.5	1918	1919	1919	1919	1919	1919	1919	1919	1918	1918	1918	1918	1918	1918
14.0	1934	1935	1935	1935	1935	1935	1935	1935	1935	1935	1934	1934	1934	1934
14.5	1950	1952	1952	1952	1951	1951	1951	1951	1951	1951	1951	1950	1950	1950
15.0	1966	1968	1968	1968	1968	1968	1968	1967	1967	1967	1967	1967	1966	1966
15.5	1982	1984	1984	1984	1983	1983	1983	1983	1983	1983	1982	1982	1982	1982
16.0	1996	1998	1998	1998	1998	1998	1998	1997	1997	1997	1997	1997	1996	1996
16.5	2009	2011	2011	2011	2011	2011	2010	2010	2010	2010	2010	2009	2009	2009
17.0	2021	2022	2022	2022	2022	2022	2022	2022	2022	2021	2021	2021	2021	2020
17.5	2032	2033	2033	2033	2033	2033	2033	2032	2032	2032	2032	2032	2032	2031
18.0	2042	2043	2043	2043	2043	2043	2042	2042	2042	2042	2042	2042	2041	2041
18.5	2051	2052	2052	2052	2052	2052	2052	2052	2051	2051	2051	2051	2051	2050
19.0	2059	2061	2061	2060	2060	2060	2060	2060	2060	2060	2060	2059	2059	2059
19.5	2067	2068	2068	2068	2067	2067	2067	2067	2067	2067	2067	2067	2066	2066
20.0	2072	2073	2073	2073	2073	2073	2073	2073	2073	2073	2073	2073	2072	2072
20.5	2077	2078	2078	2078	2078	2078	2078	2078	2078	2078	2078	2077	2077	2077
21.0	2083	2084	2084	2084	2084	2084	2084	2084	2084	2084	2083	2083	2083	2083
21.5	2090	2092	2092	2092	2091	2091	2091	2091	2091	2090	2090	2090	2090	2090
22.0	2099	2102	2102	2101	2101	2101	2101	2100	2100	2100	2100	2099	2099	2098
22.5	2110	2113	2112	2112	2112	2112	2111	2111	2111	2111	2110	2110	2109	2109
23.0	2121	2124	2124	2124	2124	2123	2123	2123	2123	2122	2122	2122	2121	2121
23.5	2132	2134	2134	2134	2134	2134	2133	2133	2133	2132	2132	2132	2132	2131
24.0	2140	2142	2142	2142	2142	2142	2141	2141	2141	2141	2140	2140	2140	2140
24.5	2146	2148	2148	2147	2147	2147	2147	2147	2147	2146	2146	2146	2146	2146
25.0	2150	2151	2151	2151	2151	2151	2151	2151	2151	2151	2151	2151	2150	2150
25.5	2153	2154	2154	2154	2154	2154	2154	2154	2154	2154	2153	2153	2153	2153
26.0	2154	2154	2154	2154	2154	2154	2154	2154	2154	2154	2154	2154	2154	2154
26.5	2154	2155	2155	2155	2155	2154	2154	2154	2154	2154	2154	2154	2154	2154
27.0	2154	2154	2154	2154	2154	2154	2154	2154	2154	2154	2154	2154	2155	2155

Table 18-1: Power curve, Sound Optimized Mode SO13



### 18.3 Sound Curves, Sound Optimized Mode SO13

Sound Power Level at Hub Height	
Conditions for Sound Power Level:	Measurement standard IEC 61400-11 ed. 3 Maximum turbulence at hub height: 30% Inflow angle (vertical): 0 ±2° Air density: 1.225 kg/m <sup>3</sup>
Wind speed at hub height [m/s]	Sound Power Level at Hub Height [dBA] Sound Optimized Mode SO13 (Blades with serrated trailing edge)
3	92.1
4	92.4
5	92.5
6	92.5
7	93.1
8	94.2
9	95.8
10	96.4
11	96.9
12	97.0
13	97.0
14	97.0
15	97.0
16	97.0
17	97.0
18	97.0
19	97.0
20	97.0

*Table 18-3: Sound curves, Sound Optimized Mode SO13*



<b>Air density [kg/m<sup>3</sup>]</b>														
<b>Wind speed [m/s]</b>	<b>1.225</b>	<b>0.950</b>	<b>0.975</b>	<b>1.000</b>	<b>1.025</b>	<b>1.050</b>	<b>1.075</b>	<b>1.100</b>	<b>1.125</b>	<b>1.150</b>	<b>1.175</b>	<b>1.200</b>	<b>1.250</b>	<b>1.275</b>
<b>28.5</b>	<b>2155</b>	2155	2155	2155	2155	2155	2155	2155	2155	2155	2155	2155	2155	2155
<b>29.0</b>	<b>2154</b>	2155	2155	2155	2155	2154	2154	2154	2154	2154	2154	2154	2154	2154
<b>29.5</b>	<b>2152</b>	2152	2152	2152	2152	2152	2152	2152	2152	2152	2152	2152	2152	2152
<b>30.0</b>	<b>2142</b>	2143	2143	2143	2143	2142	2142	2142	2142	2142	2142	2142	2142	2142
<b>30.5</b>	<b>2093</b>	2094	2094	2094	2094	2094	2094	2094	2094	2094	2093	2093	2093	2093
<b>31.0</b>	<b>1979</b>	1979	1979	1979	1979	1979	1979	1979	1979	1979	1979	1979	1979	1979
<b>31.5</b>	<b>1837</b>	1837	1837	1837	1837	1837	1837	1837	1837	1837	1837	1837	1837	1837
<b>32.0</b>	<b>1715</b>	1715	1715	1715	1715	1715	1715	1715	1715	1715	1715	1715	1715	1715

*Table 19-1: Power curve, Sound Optimized Mode SO13 (HWO)*





### 19.3 Sound Curves, Sound Optimized Mode SO13 (HWO)

Sound Power Level at Hub Height	
Conditions for Sound Power Level:	Measurement standard IEC 61400-11 ed. 3 Maximum turbulence at hub height: 30% Inflow angle (vertical): 0 ±2° Air density: 1.225 kg/m <sup>3</sup>
Wind speed at hub height [m/s]	Sound Power Level at Hub Height [dBA] Sound Optimized Mode SO13 (HWO) (Blades with serrated trailing edge)
3	92.1
4	92.4
5	92.5
6	92.5
7	93.1
8	94.2
9	95.8
10	96.4
11	96.9
12	97.0
13	97.0
14	97.0
15	97.0
16	97.0
17	97.0
18	97.0
19	97.0
20	97.0

*Table 19-3: Sound curves, Sound Optimized Mode SO13 (HWO)*

## 20 Power Curves, Ct Values and Sound Curves, Load Optimized Mode LO1

**NOTE** The power curves and Ct values presented in Section 20 are only valid for low hub heights, i.e. hub heights ≤ 104 m.

### 20.1 Power Curves, Load Optimized Mode LO1

Wind speed [m/s]	Air density [kg/m <sup>3</sup> ]													
	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	55	31	33	35	38	40	42	44	46	48	51	53	57	59
3.5	130	89	93	97	100	104	108	111	115	119	122	126	133	137
4.0	220	159	165	170	176	182	187	193	198	204	209	215	226	231
4.5	331	245	253	260	268	276	284	292	299	307	315	323	338	346
5.0	471	353	364	374	385	396	407	417	428	439	449	460	481	492
5.5	639	483	497	511	526	540	554	568	582	596	610	624	653	667
6.0	841	640	659	677	695	714	732	750	768	787	805	823	860	878
6.5	1080	826	849	872	895	919	942	965	988	1011	1034	1057	1104	1127
7.0	1361	1044	1073	1102	1131	1160	1189	1218	1247	1276	1304	1333	1390	1419
7.5	1681	1293	1329	1364	1399	1435	1470	1505	1541	1576	1611	1646	1715	1750
8.0	2042	1578	1620	1663	1706	1748	1790	1833	1875	1917	1959	2000	2083	2124
8.5	2441	1897	1947	1998	2048	2099	2148	2198	2247	2296	2345	2393	2488	2535
9.0	2845	2242	2300	2358	2415	2473	2527	2582	2636	2691	2742	2794	2894	2943
9.5	3208	2591	2652	2713	2774	2836	2891	2947	3003	3058	3108	3158	3253	3298
10.0	3497	2923	2984	3046	3107	3168	3220	3271	3322	3374	3415	3456	3529	3562
10.5	3678	3221	3277	3333	3389	3444	3484	3522	3562	3600	3626	3652	3696	3714
11.0	3767	3456	3499	3542	3585	3628	3653	3678	3703	3728	3741	3754	3774	3781
11.5	3795	3631	3658	3685	3712	3740	3751	3762	3773	3784	3787	3791	3796	3798
12.0	3799	3733	3746	3759	3772	3785	3788	3791	3795	3798	3798	3799	3800	3800
12.5	3800	3777	3782	3787	3792	3798	3798	3799	3799	3800	3800	3800	3800	3800
13.0	3800	3793	3794	3796	3798	3800	3800	3800	3800	3800	3800	3800	3800	3800
13.5	3800	3796	3796	3798	3798	3800	3800	3800	3800	3800	3800	3800	3800	3800
14.0	3800	3798	3798	3799	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800
14.5	3800	3799	3799	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800
15.0	3800	3799	3799	3799	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800
15.5	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800
16.0	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800
16.5	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800
17.0	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800
17.5	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800
18.0	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800
18.5	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800
19.0	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800
19.5	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800
20.0	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800
20.5	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800
21.0	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800
21.5	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800
22.0	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800
22.5	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800
23.0	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800
23.5	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800
24.0	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800
24.5	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800
25.0	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800
25.5	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800
26.0	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800
26.5	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800
27.0	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800	3800

Table 20-1: Power curve, Load Optimized Mode LO1



### 20.3 Sound Curves, Load Optimized Mode LO1

Sound Power Level at Hub Height	
Conditions for Sound Power Level:	Measurement standard IEC 61400-11 ed. 3 Maximum turbulence at hub height: 30% Inflow angle (vertical): 0 ±2° Air density: 1.225 kg/m <sup>3</sup>
Wind speed at hub height [m/s]	Sound Power Level at Hub Height [dBA] Load Optimized Mode LO1 (Blades with serrated trailing edge)
3	90.9
4	91.1
5	92.8
6	95.9
7	99.5
8	102.8
9	103.9
10	103.9
11	103.9
12	103.9
13	103.9
14	103.9
15	103.9
16	103.9
17	103.9
18	103.9
19	103.9
20	103.9

*Table 20-3: Sound curves, Load Optimized Mode LO1*



Air density [kg/m <sup>3</sup> ]														
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
<b>28.5</b>	<b>3275</b>	3275	3275	3275	3275	3275	3275	3275	3275	3275	3275	3275	3275	3275
<b>29.0</b>	<b>3049</b>	3049	3049	3049	3049	3049	3049	3049	3049	3049	3049	3049	3049	3049
<b>29.5</b>	<b>2806</b>	2806	2806	2806	2806	2806	2806	2806	2806	2806	2806	2806	2806	2806
<b>30.0</b>	<b>2565</b>	2565	2565	2565	2565	2565	2565	2565	2565	2565	2565	2565	2565	2565
<b>30.5</b>	<b>2324</b>	2324	2324	2324	2324	2324	2324	2324	2324	2325	2325	2325	2325	2324
<b>31.0</b>	<b>2090</b>	2090	2090	2090	2090	2090	2090	2090	2090	2090	2090	2090	2090	2090
<b>31.5</b>	<b>1884</b>	1884	1884	1884	1884	1884	1884	1884	1884	1884	1884	1884	1884	1884
<b>32.0</b>	<b>1732</b>	1732	1732	1732	1732	1732	1732	1732	1732	1732	1732	1732	1732	1732

*Table 21-1: Power curve, Load Optimized Mode LO1 (HWO)*





**21.3 Sound Curves, Load Optimized Mode LO1 (HWO)**

Sound Power Level at Hub Height	
Conditions for Sound Power Level:	Measurement standard IEC 61400-11 ed. 3 Maximum turbulence at hub height: 30% Inflow angle (vertical): 0 ±2° Air density: 1.225 kg/m <sup>3</sup>
Wind speed at hub height [m/s]	Sound Power Level at Hub Height [dBA] Load Optimized Mode LO1 (HWO) (Blades with serrated trailing edge)
3	90.9
4	91.1
5	92.9
6	96.0
7	99.6
8	102.9
9	103.9
10	103.9
11	103.9
12	103.9
13	103.9
14	103.9
15	103.9
16	103.9
17	103.9
18	103.9
19	103.9
20	103.9

Table 21-3: Sound curves, Load Optimized Mode LO1 (HWO)





### 22.3 Sound Curves, Load Optimized Mode LO2

Sound Power Level at Hub Height	
Conditions for Sound Power Level:	Measurement standard IEC 61400-11 ed. 3 Maximum turbulence at hub height: 30% Inflow angle (vertical): 0 ±2° Air density: 1.225 kg/m <sup>3</sup>
Wind speed at hub height [m/s]	Sound Power Level at Hub Height [dBA] Load Optimized Mode LO2 (Blades with serrated trailing edge)
3	90.9
4	91.1
5	92.8
6	95.9
7	99.5
8	102.1
9	102.5
10	102.5
11	102.5
12	102.5
13	102.5
14	102.5
15	102.5
16	102.5
17	102.5
18	102.5
19	102.5
20	102.5

*Table 22-3: Sound curves, Load Optimized Mode LO2*



Air density [kg/m <sup>3</sup> ]														
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
<b>28.5</b>	<b>3270</b>	3270	3270	3270	3270	3270	3270	3270	3270	3270	3270	3270	3270	3270
<b>29.0</b>	<b>3049</b>	3049	3049	3049	3049	3049	3049	3049	3049	3049	3049	3049	3049	3049
<b>29.5</b>	<b>2806</b>	2806	2806	2806	2806	2806	2806	2806	2806	2806	2806	2806	2806	2806
<b>30.0</b>	<b>2565</b>	2565	2565	2565	2565	2565	2565	2565	2565	2565	2565	2565	2565	2565
<b>30.5</b>	<b>2324</b>	2324	2324	2324	2325	2325	2325	2325	2325	2325	2324	2324	2324	2324
<b>31.0</b>	<b>2090</b>	2090	2090	2090	2090	2090	2090	2090	2090	2090	2090	2090	2090	2090
<b>31.5</b>	<b>1884</b>	1884	1884	1884	1884	1884	1884	1884	1884	1884	1884	1884	1884	1884
<b>32.0</b>	<b>1732</b>	1732	1732	1732	1732	1732	1732	1732	1732	1732	1732	1732	1732	1732

*Table 23-1: Power curve, Load Optimized Mode LO2 (HWO)*



### 23.3 Sound Curves, Load Optimized Mode LO2 (HWO)

Sound Power Level at Hub Height	
Conditions for Sound Power Level:	Measurement standard IEC 61400-11 ed. 3 Maximum turbulence at hub height: 30% Inflow angle (vertical): 0 ±2° Air density: 1.225 kg/m <sup>3</sup>
Wind speed at hub height [m/s]	Sound Power Level at Hub Height [dBA] Load Optimized Mode LO2 (HWO) (Blades with serrated trailing edge)
3	90.9
4	91.1
5	92.8
6	95.9
7	99.5
8	102.1
9	102.5
10	102.5
11	102.5
12	102.5
13	102.5
14	102.5
15	102.5
16	102.5
17	102.5
18	102.5
19	102.5
20	102.5

*Table 23-3: Sound curves, Load Optimized Mode LO2 (HWO)*