group hope SANTA CHIARA

PROGETTO PER LA REALIZZAZIONE DI UN IMPIANTO PER LA PRODUZIONE DI ENERGIA MEDIANTE LO SFRUTTAMENTO DEL VENTO NEL TERRITORIO COMUNALE DI CAMUGNANO (BO) LOC. TRASSERRA POTENZA NOMINALE 27 MW

PROGETTO DEFINITIVO - SIA

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R.3.1 Scheda tecnica aerogeneratore

REV.	DATA	DESCRIZIONE

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General Description

4MW Platform

4.5MW

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1 Introduction

The 4MW Platform wind turbine configurations covered by this General Description are listed below with designations according to IECRE OD-501 Ed.2.

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

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
V163-4.5 MW	V163-4.5 MW IEC 3B 50/60 Hz	Power Optimized Mode (PO4500)
V166-4.5MW	V166-4.5MW IEC 3C 50/60Hz	Power Optimized Mode (PO4500)

Table 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 rotor diameters from 105 to 166 meter and Power ratings from 3.3 to 4.5 MW.

This General Description, and the 4.5 MW Power Optimized Mode, only applies to V163-4.5 MW and V166-4.5MW.

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

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.

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	V163	V166
Diameter	163 m	166 m

Rotor	V163	V166
Swept Area	20.867 m^2	21.642 m^2
Speed, Dynamic Operation Range	4.3-11.0	
Rotational Direction	Clockwise (front view)	
Orientation	Upwind	
Tilt	6°	
Hub Coning	3°	
No. of Blades	3	
Aerodynamic Brakes	Full feathering	

Table 2: 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	V163	V166
Type Description	Infused structural airfoil shell	
Blade Length	80.1 m	81.6 m
Material	Fibreglass reinforced epoxy, carbon fibres and Solid Metal Tip (SMT)	
Blade Connection	Steel roots inserted	
Airfoils	High-lift profile	
Maximum Chord	4.3 m	
Chord at 90% blade radius	1.3 m	

Table 3: Blades data

3.3 Blade Bearing

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

Blade Bearing	
Blade bearing type	3-rows roller bearings
Lubrication	Manual grease lubrication

Table 4: 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	-8.5° to 95°

Table 5: Pitch system data

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

Table 6: 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 7: 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 8: 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 9: 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 10: 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 11: 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

Yaw 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 12: 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 13: 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 14: 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.

For site specific hub height requests, please contact Vestas.

Towers	
Type	Cylindrical/conical tubular

Table 15: 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 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**
Nacelle Cover	GRP
Bedplate Front	Cast iron
Bedplate Rear	Girder structure

Table 16: Nacelle bedplate and cover data

3.16 Thermal Conditioning System

The thermal conditioning system consists of a few robust components:

- The Vestas CoolerTop® located on top of the rear end of the nacelle. The CoolerTop® is a free flow cooler, thus ensuring that there are no electrical components in the thermal conditioning system located outside the nacelle.
- The CoolerTop® comes as standard in a “naked” form, with no side cover panels.
- 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.
- The nacelle 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	
Type	Asynchronous with cage rotor
Rated Power [P_N]	4800 kW
Frequency [f_N]	0-100 Hz
Voltage, Stator [U_{NS}]	3 x 800 V (at rated speed)
Number of Poles	6

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

Table 17: 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	
Rated Apparent Power [S_N]	5300 kVA
Rated Grid Voltage	3 x 720 V
Rated Generator Voltage	3 x 800 V
Rated Grid Current @ 0.9 p.u. Voltage	4250 A
Rated Generator Current	3925 A
Enclosure	IP54

Table 18: 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)[1].
- Eco-design based on Tier 2 requirements (effective in EU from 1 July 2021)[1].

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	5300 kVA
Rated voltage, turbine side	
U_m 1.1kV	0.720 kV
Rated voltage, grid side	
U_m 24.0kV	15.7-22.0 kV
U_m 36.0kV	22.1-33.0 kV
U_m 40.5kV	33.1-36.0 kV
Insulation level AC / LI / LIC	
U_m 1.1kV	3^2 / 3 / 3 kV
U_m 24.0kV	50^2 / 125 / 125 kV
U_m 36.0kV	70^2 / 170 / 170 kV
U_m 40.5kV	80^2 / 170 / 170 kV
Off-circuit tap changer	±2 x 2.5 %
Frequency	50 Hz / 60 Hz
Vector group	Dyn5
No-load current [3]	~0.5 %
Positive sequence short-circuit impedance @ rated power, reference temperature according to IEC 60076-11 [4]	9.9 %
Positive sequence short-circuit resistance@ rated power, reference temperature according to IEC 60076-11 [3]	~0.8 %
Zero sequence short-circuit impedance@ rated power, reference temperature according to IEC 60076-11 [3]	~8.3 %
Zero sequence short-circuit resistance@ rated power,	~0.7 %

Transformer	
reference temperature according to IEC 60076-11 [3]	
No-load reactive power [3]	~20 kVAr
Full load reactive power [3]	~550 kVAr
Inrush peak current [3]	5-8 x $\hat{I}_n$ A
Half crest time [3]	~ 0.6 s
Sound power level	≤ 80 dB(A)
Average temperature rise at max altitude	≤ 90 K
Max altitude [5]	2000 m
Insulation class	
LV coil	155 (F)
HV coil	155 (F) or 180 (H)
Environmental class	E2
Climatic class	C2
Fire behaviour class	F1
Corrosion class	C4
Weight	≤11000 kg
Temperature monitoring	PT100 sensors in LV windings and core
Overvoltage protection	Surge arresters on HV terminals
Temporary earthing	3 x Ø25 mm earthing ball points

Table 19: 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 1 and Figure 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.

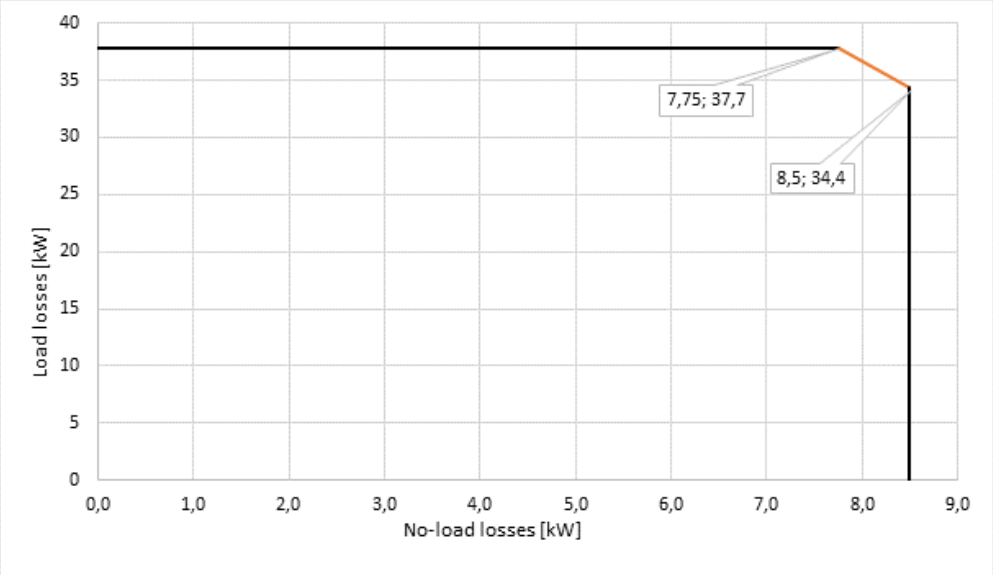


Figure 1: Transformer losses allowable area for Tier 1

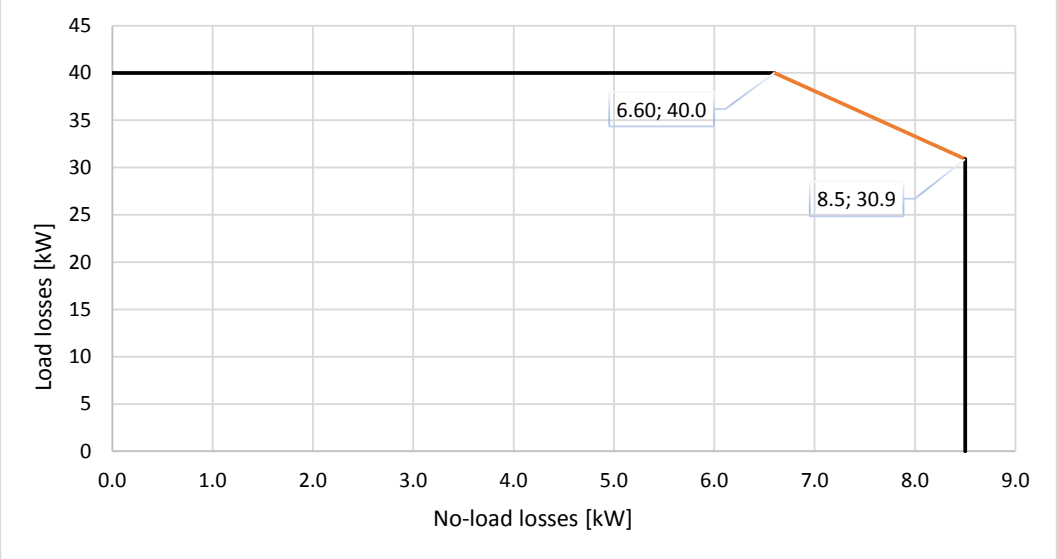


Figure 2: Transformer losses allowable area for Tier 2

The actual load losses vary depend on the operation mode of the turbine, hence in Table 20 the load losses are provided at different operation modes for the two loss variants. For further recalculation of load losses at different operation modes, refer to Figure 3.

Transformer losses Tier 1	
Peak Efficiency Index (PEI)	> 99.354
Loss variant 1	
No-load loss	7.75 kW
Load loss @ power, reference temperature according to IEC 60076-11	**@5300kVA** ≤ 37.7 kW
Loss variant 2	
No-load loss	8.5 kW
Load loss @ power, reference temperature according to IEC 60076-11	**@5300kVA** ≤ 34.4 kW
Transformer losses Tier 2	
Peak Efficiency Index (PEI)	> 99.387
Loss variant 1	
No-load loss	6.6 kW
Load loss @ power, reference temperature according to IEC 60076-11	**@5300kVA** ≤ 40.0 kW
Loss variant 2	
No-load loss	8.5 kW
Load loss @ power, reference temperature according to IEC 60076-11	**@5300kVA** ≤ 30.9 kW

Table 20: Transformer losses for Eco-designs IEC 50 Hz/60 Hz version.

NOTE

[1] The date reflects date for shipment of transformer from manufacturer.

[2] @1000m. According to IEC 60076-11, AC test voltage is altitude dependent.
[3] Based on an average of calculated values across voltages and manufacturers.
[4] Subjected to standard IEC tolerances.
[5] 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.

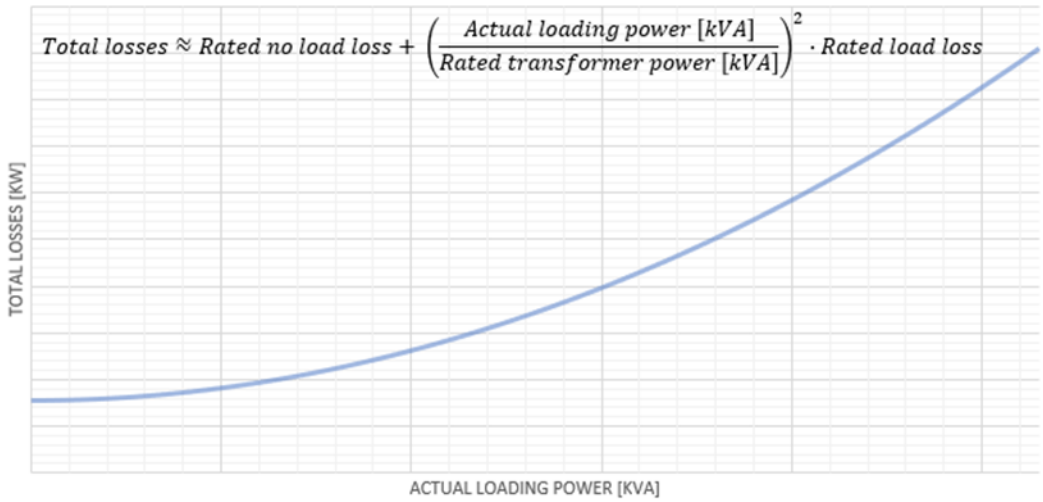


Figure 3: Total Losses vs. Actual Power

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.

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

Table 21: 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 22. 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 23 for the IEC version and in Table 24 for the IEEE version.

HV Switchgear			
Variant	**Basic**	**Streamline**	**Standard**
IEC standards	○	⊙	⊙
IEEE standards	⊙	○	⊙
Vacuum circuit breaker panel	⊙	⊙	⊙
Overcurrent, short-circuit and earth fault protection	⊙	⊙	⊙
Disconnector / earthing switch in circuit breaker panel	⊙	⊙	⊙
Voltage Presence Indicator System for circuit breaker	⊙	⊙	⊙
Voltage Presence Indicator System for grid cables	⊙	⊙	⊙
Double grid cable connection	⊙	⊙	⊙
Triple grid cable connection	⊙	○	○
Preconfigured relay settings	⊙	⊙	⊙
Turbine safety system integration	⊙	⊙	⊙
Redundant trip coil circuits	⊙	⊙	⊙

HV Switchgear			
Variant	**Basic**	**Streamline**	**Standard**
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 22: HV switchgear variants and features

4.5.1 IEC 50/60Hz version

HV Switchgear	
Type description	Gas Insulated Switchgear
Applied standards	IEC 62271-103 IEC 62271-1, 62271-100, 62271-102, 62271-200, IEC 60694
Insulation medium	SF_6
Rated voltage	
U_r 24.0kV	15.7-22.0 kV
U_r 36.0kV	22.1-33.0 kV
U_r 40.5kV	33.1-36.0 kV
Rated insulation level AC // LI Common value / across isolation distance	
U_r 24.0kV	50 / 60 // 125 / 145 kV
U_r 36.0kV	70 / 80 // 170 / 195 kV
U_r 40.5kV	85 / 90 // 185 / 215 kV
Rated frequency	50 Hz / 60 Hz
Rated normal current	630 A
Rated Short-time withstand current	
U_r 24.0kV	20 kA
U_r 36.0kV	25 kA
U_r 40.5kV	25 kA

HV Switchgear	
Rated peak withstand current 50 / 60 Hz	
U_r 24.0kV	50 / 52 kA
U_r 36.0kV	62.5 / 65 kA
U_r 40.5kV	62.5 / 65 kA
Rated duration of short-circuit	1 s
Internal arc classification (option)	
U_r 24.0kV	IAC A FLR 20 kA, 1 s
U_r 36.0kV	IAC A FLR 25 kA, 1 s
U_r 40.5kV	IAC A FLR 25 kA, 1 s
Connection interface	Outside cone plug-in bushings, IEC interface C1.
Loss of service continuity category	LSC2
Ingress protection	
Gas tank	IP 65
Enclosure	IP 2X
LV cabinet	IP 3X
Corrosion class	C3

Table 23: HV switchgear data for IEC version

4.5.2 IEEE 60Hz version

HV Switchgear	
Type description	Gas Insulated Switchgear
Applied standards	IEEE 37.20.3, IEEE C37.20.4, IEC 62271-200, ISO 12944.
Insulation medium	SF_6
Rated voltage	
U_r 38.0kV	22.1-36.0 kV
Rated insulation level AC / LI	70 / 150 kV
Rated frequency	60 Hz
Rated normal current	600 A
Rated Short-time withstand current	25 kA
Rated peak withstand current	65 kA
Rated duration of short-circuit	1 s
Internal arc classification (option)	IAC A FLR 25 kA, 1 s
Connection interface grid cables	Outside cone plug-in bushings, IEEE 386 interface type deadbreak, 600A.
Ingress protection	
Gas tank	NEMA 4X / IP 65
Enclosure	NEMA 2 / IP 2X
LV cabinet	NEMA 2 / IP 3X
Corrosion class	C3

Table 24: 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 25: 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® - 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	60 days***

Table 26: UPS data

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

Table 27: 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 and battery panels.*

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

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

NOTE For alternative backup times, consult Vestas.

5 Turbine Protection Systems

5.1 Braking Concept

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

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

5.2 Short Circuit Protections

Breakers	**Breaker for Aux. Power.** **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 Icu, Ics	75 kA rms @ max 840 V Ics = 100%	66 kA rms @ max 1000 V Ics = 100%	66 kA rms @ max 1000 V Ics = 100%
Making Capacity Icm	166 kA peak @ max 840 V	145 kA peak @ max 1000 V	145 kA peak @ max 1000 V

Table 28: 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	11.0-12.7 rpm / 2000 (generator rpm)

Table 29: 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.

V163/V166 blades:

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

Table 30 Lightning protection design parameters (IEC)

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 31 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_2 fire extinguisher, first aid kit and fire blanket are required to be located in the nacelle during service and maintenance.

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

6.12 Warning Signs

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

6.13 Manuals and Warnings

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

7 Environment

7.1 Chemicals

Chemicals used in the turbine are evaluated according to the Vestas Wind Systems A/S Environmental System certified according to ISO 14001:2015. 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 Ed.3 & 4
Tower	IEC 61400-1 Ed. 4 Eurocode 3
Blades	IEC 61400-5 IEC 61400-24:2019 IECRE OD-501

Design Codes	
Gearbox	IEC 61400-4
Generator	IEC 60034
Transformer	IEC 60076-11, IEC 60076-16, CENELEC HD637 S1
Lightning Protection	IEC 62305-1: 2006 IEC 62305-3: 2006 IEC 62305-4: 2006 IEC 61400-24:2010 IEC 61400-24:2019
Rotating Electrical Machines	IEC 34
Safety of Machinery, Safety-related Parts of Control Systems	ISO 13849-1
Safety of Machinery – Electrical Equipment of Machines	IEC 60204-1

Table 32: Design codes

9 Colours

9.1 Nacelle Colour

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

Table 33: Colour, nacelle

9.2 Tower Colour

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

Table 34: Colour, tower

9.3 Blade Colour

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

Blade Colour	
Gloss	< 30% DS/EN ISO 2813

Table 35: Colour, blades

10 Operational Envelope and Performance Guidelines

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

10.1 Climate and Site Conditions

Values refer to hub height:

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

Table 36: Extreme design parameters

10.2 Operational Envelope – Temperature and Altitude

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

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

Table 37: Operational envelope – temperature

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

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

Figure 4 illustrate performance for high temperature cooler top.

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 figure the turbine will maintain derated production. The derate values depend of the altitude of the turbine.

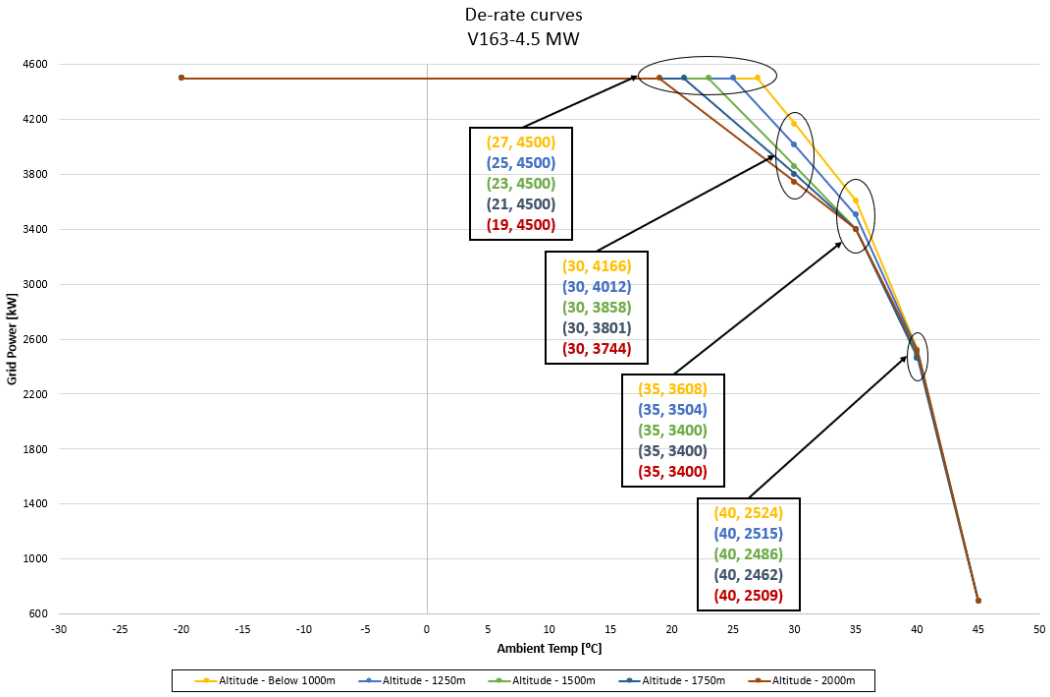


Figure 4: Temperature dependant derated operation

10.4 Operational Envelope – Grid Connection

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

Table 38: Operational envelope – grid connection

The generator and the converter will be disconnected if*:

Protection Settings	
Voltage Above 110% of Nominal for 1800 Seconds**	792 V
Voltage Above 116% of Nominal for 60 Seconds	835 V
Voltage Above 125% of Nominal for 2 Seconds	900 V
Voltage Above 136% of Nominal for 0.150 Seconds	979 V
Voltage Below 90% of Nominal for 180 Seconds (FRT)**	648 V
Voltage Below 85% of Nominal for 12 Seconds (FRT)	612 V
Voltage Below 80% of Nominal for 4.8 Seconds (FRT)	576 V
Frequency is Above 106% of Nominal for 0.2 Seconds	53/63.6 Hz
Frequency is Below 94% of Nominal for 0.2 Seconds	47/56.4 Hz

Table 39: Generator and converter disconnecting values

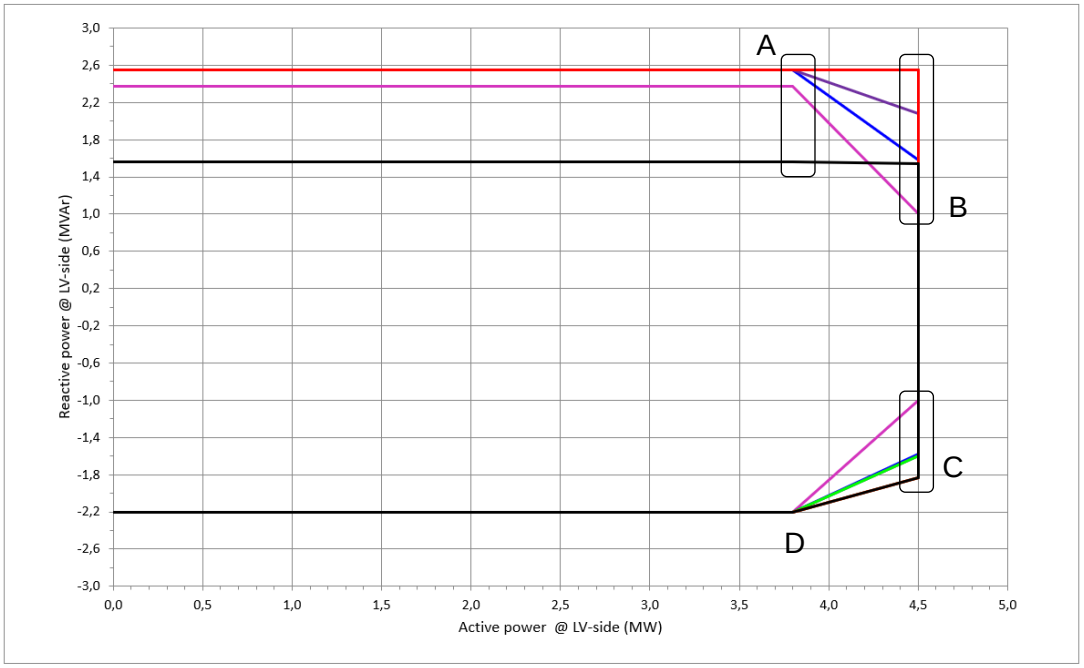
NOTE

* 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 4.5 MW PO4500

The reactive power capability for the 4.5 MW Power Optimized Mode (PO4500) is as illustrated in Figure 6:



	Point:	Coordinates								Power factor	
		A		B		C		D			
	Coordinate:	x (P)	y (Q)	x (P)	y (Q)	x (P)	y (Q)	x (P)	y (Q)	B (Capacitive)	C (Inductive)
	Q @ LV side @ 0.87 p.u. voltage	3,800	2,370	4,500	1,005	4,500	-1,005	3,800	-2,200	0,98	0,98
	Q @ LV side @ 0.90 p.u. voltage	3,800	2,550	4,500	1,582	4,500	-1,582	3,800	-2,200	0,94	0,94
	Q @ LV side @ 0.95 p.u. voltage	3,800	2,550	4,500	2,076	4,500	-1,600	3,800	-2,200	0,91	0,94
	Q @ LV side @ 1.00 p.u. voltage	3,800	2,550	4,500	2,550	4,500	-1,600	3,800	-2,200	0,87	0,94
	Q @ LV side @ 1.05 p.u. voltage	3,800	2,550	4,500	2,550	4,500	-1,830	3,800	-2,200	0,87	0,93
	Q @ LV side @ 1.10 p.u. voltage	3,800	2,550	4,500	2,550	4,500	-1,830	3,800	-2,200	0,87	0,93
	Q @ LV side @ 1.13 p.u. voltage	3,800	1,560	4,500	1,542	4,500	-1,830	3,800	-2,200	0,95	0,93

Figure 5 - Reactive power capability for 4.5 MW Power Optimized Mode (PO4500).

When operating at 4.5 MW in Power Optimized Mode (PO4500) at LV side of the HV transformer, the reactive power capability on the high voltage side of the HV transformer is approximately:

- cosφ(HV) = 0.98/0.91 capacitive/inductive @ U(HV) = 0.90 p.u. voltage
- cosφ(HV) = 0.91/0.88 capacitive/inductive @ U(HV) = 1.10 p.u. voltage

The turbine can maintain the reactive power capability with no active power production within cut-in and cut-out wind speed limits.

10.6 Operational Envelope – Temperature dependent Reactive Power Capability

The reactive power capabilities shown in Figure 5 are valid for ambient temperatures at which no active power derate is needed according to Figure 4.

For ambient temperatures up to 40°C, where active power is derated as a consequence of ambient temperature, the shape of the PQ chart (Figure 5: 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 4.

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

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

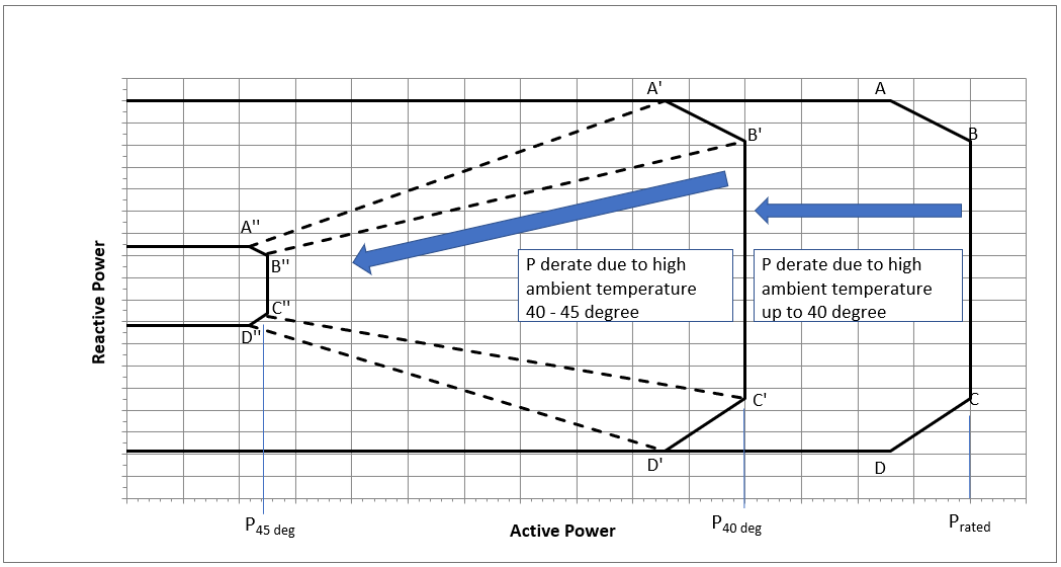


Figure 6: Reactive power capability temperature dependency. Illustrative example.

10.7 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:

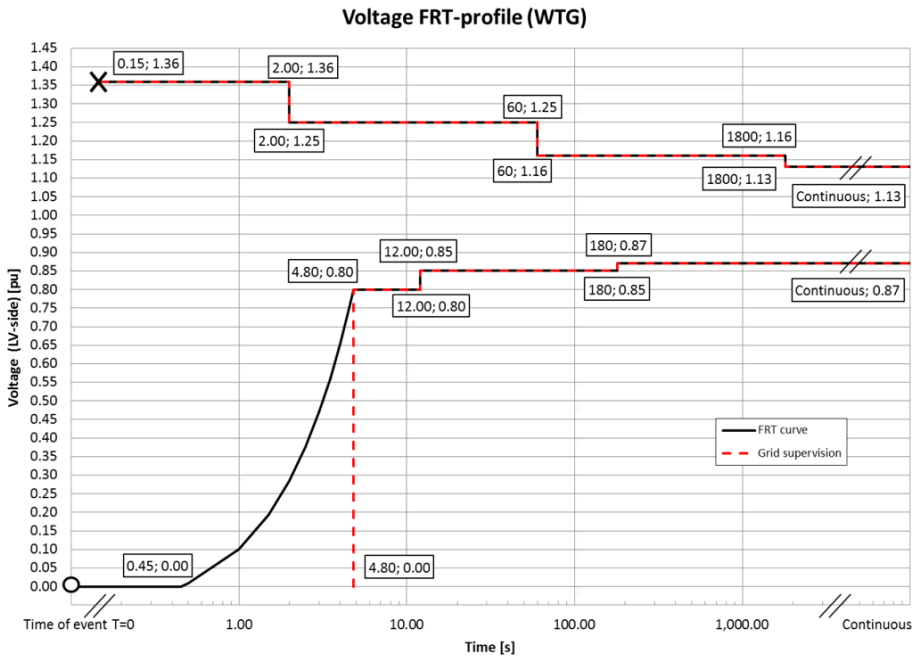


Figure 7: Voltage tolerance curve for symmetrical and asymmetrical faults, where U represents voltage as measured on the grid

For grid disturbances outside the tolerance curve in Figure 7, the turbine will be disconnected from the grid

.

Power Recovery Time		
Power Recovery to 90% of Pre-Fault Level	fault with duration <140 ms	Fault with duration >140 ms
	Maximum 0.1 s	Maximum 0.5 s

Table 40: Power recovery time

10.8 Performance – Reactive Current Contribution

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

10.8.1 Symmetrical Reactive Current Contribution

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

The default value gives a reactive current part of 1 p.u. of the rated active current at the high voltage side of the HV transformer. Figure 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 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.

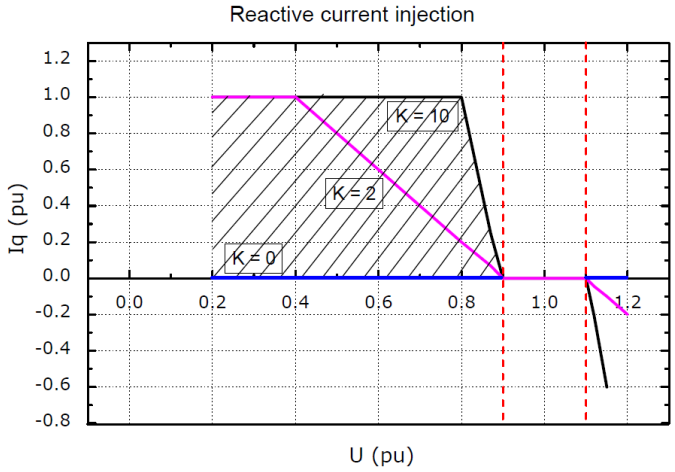


Figure 8: Reactive current injection

10.8.2 Asymmetrical Reactive Current Contribution

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

10.9 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.

10.10 Performance – Active and Reactive Power Control

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

Maximum Ramp Rates for External Control	
Active Power	0.1 p.u./sec for max. power level change of 0.3 p.u. 0.3 p.u./sec for max. power level change of 0.1 p.u.
Reactive Power	20 p.u./sec

Table 41: 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.

10.11 Performance – Voltage Control

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

10.12 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.

10.13 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%.

10.14 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 42 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.

Main contributors to Own Consumption	
Hydraulic Motor	2 x 22 kW (master-slave)
Yaw Motors	Maximum 24.3 kW in total
Generator Cooling	15 kW
Water Heating	10.8 kW
Water Pumps	2.2 + 4.0 kW
Oil Pump for Gearbox Lubrication	7.5 kW
Controller Including Heating Elements for the Hydraulics and all Controllers	Approximately 3 kW
Nacelle Cooling	1.0 kW
HV Transformer Cooling	3.6 kW
HV Transformer No-load Loss	See section 4.3 HV Transformer, p. 12

Table 42: Main contributors to own consumption data.

11 Drawings

11.1 Structural Design – Illustration of Outer Dimensions

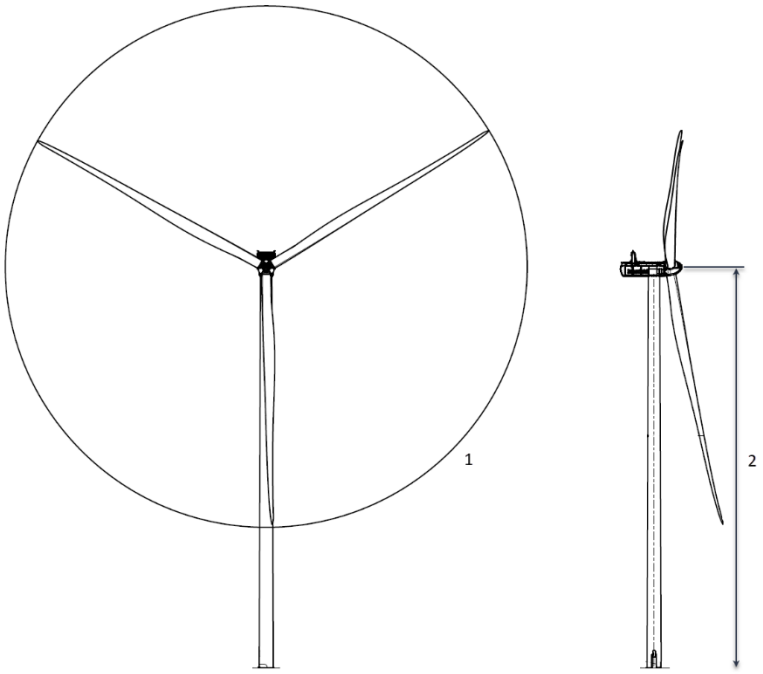


Figure 9: Illustration of outer dimensions – structure

1 Rotor diameter: 163/166 m

2 Hub heights: See Performance Specification

11.2 Structural Design – Side View Drawing

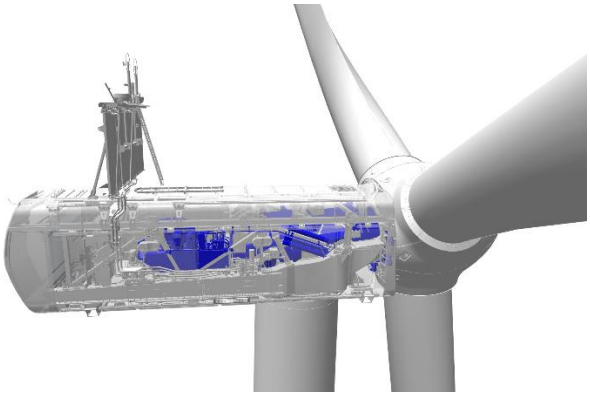


Figure 10: Side-view drawing

12 General Reservations, Notes and Disclaimers

-
- 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.

Restricted
Document no.: 0130-7822.V05
2023-11-14

Performance Specification

V163–4.5 MW 50/60 Hz

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

Table of Contents

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

1 Introduction

The Vestas V163-4.5 MW wind turbine is a pitch regulated upwind turbine with active yaw and a three-blade rotor. The Vestas V163-4.5 MW turbine has a rotor diameter of 163 m.

This Performance Specification contains power curves, Ct curves and sound curves for V163-4.5 MW

2 Certification and Available Hub Heights

The standard turbine is type certified according to IECRE OD-501. Available hub heights are listed below:

Certification	Wind Class	Hub Height
Tower type		**Standard**
IECRE OD-501	IECS	HH98, HH113, HH126

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

Tower height configuration can further be evaluated project specifically. Consult Vestas for specific tower request.

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 operated in 4.5 MW Power Optimized Mode PO4 with the wind climate conditions listed below. Values refer to hub height.

Wind Climate	**IEC IIIB**
Power Rating	**4.5 MW**
Extreme Wind Speed (10 min average), V_{50}	37.5 m/s
Survival Wind Speed (3 s gust), V_{e50}	52.5 m/s
Turbulence Intensity, I_{V50}	11%

Table 3-1: Extreme design parameters – IEC

Wind Climate	**IEC IIIB**
Power Rating	**4.5 MW**
Wind Speed (10 min average), V_{ave}	7.5 m/s
Weibull K	2.0
I_{ref} acc. to IEC 61400-1	0.14
Turbulence Intensity acc. to IEC 61400-1, Including Wind Farm Turbulence (@15 m/s) I_{90} (90% quantile)	15.7%
Wind Shear, α	0.2
Inflow Angle (vertical)	8°

Table 3-2: Average design parameters – IEC

The wind shear power law exponent shall be valid for the wind profile between the turbine lower tip and upper tip height.

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

The operation envelope is listed in Table 3-3. The turbine has the High Wind Operation (HWO) control feature as standard.

Wind Climate	**IEC IIIB**
Power Rating	**4.5 MW**
Cut-In, V_{in}	3.0 m/s
HWO start wind speed (10 min exponential avg.)	16.5 m/s
HWO cut-out wind speed	24.0 m/s
HWO re-cut-in wind speed	22.0 m/s

Table 3-3: Operational envelope – wind – IEC

4 Power Curves

The power curve is calculated for the 4.5 MW Power Mode (PO4500-0S).

4.1 Conditions for Power Curve and Ct Values

In Section 6 the power curve and Ct values are given. The power curve and Ct values are based the criteria in Table 4-1.

Conditions for Power Curve and C_t Values (at Hub Height)	
Wind Shear, *α*	0.00-0.30 (10 minute average)
Turbulence Intensity, *I*	6-12% (10 minute average)
Blades	Clean
Rain	No
Ice/Snow on Blades	No
Leading Edge	No damage
Terrain	IEC 61400-12-1
Inflow Angle (Vertical)	0 ±2°
Grid Voltage	Nominal Voltage ±2.5%
Grid Frequency	Nominal Frequency ±0.5 Hz
Grid Active Power (LV-side)	Per tabulated values in Section 6 and following sections
Grid Reactive Power (LV-side)	Power Factor 1.0

Table 4-1: Conditions for power curve and Ct values at hub height

4.2 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**
PO4500-0S	108.4 dBA	No (standard)	98, 113 & 126
PO4500	106.3 dBA	Yes (optional)	98, 113 & 126

Table 4-2: Available sound performance

The 4.5MW turbine is as standard equipped without serrated trailing edges on the blades. Optionally, the turbine can be offered with 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 [dBA]**	**Serrated trailing edges**	**Available hub heights [m]**
SO1	105.0	Yes	98, 113 & 126
SO2	103.5	Yes	98, 113 & 126
SO3	100.0	Yes	98, 113 & 126
SO12	100.0	Yes	113 & 126
SO11	99.2	Yes	113 & 126
SO13	97.0	Yes	113 & 126

Table 4-3: Available Sound Optimized modes

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.

5 General Reservations, Notes and Disclaimers

-
- In the event that Vestas supplies an updated version of the V163-4.5 MW wind turbine, Vestas will provide an updated performance specification applicable to the updated version.
- All listed start/stop parameters (e.g. wind speeds) are equipped with hysteresis control. This can, in certain borderline situations, result in turbine stops even though the ambient conditions are within the listed operation parameters.
- This document, Performance Specification, is not an offer for sale, and does not contain any guarantee, warranty and/or verification of the power curve and sound (including, without limitation, the power curve and sound verification method). Any guarantee, warranty and/or verification of the power curve and sound (including, without limitation, the power curve and sound verification method) must be agreed to separately in writing.

6 Power Curves, Power Optimized Mode PO4500-0S/PO4500

Air density [kg/m³]														
WS [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	**94**	58	61	65	68	71	74	78	81	84	87	90	97	100
3.5	**200**	142	147	152	158	163	168	174	179	184	190	195	206	211
4.0	**333**	245	253	261	269	277	285	293	301	309	317	325	341	349
4.5	**496**	372	383	395	406	417	429	440	451	462	474	485	507	519
5.0	**698**	529	544	560	575	591	606	621	637	652	667	683	713	728
5.5	**944**	720	741	761	781	802	822	842	863	883	903	924	964	984
6.0	**1237**	948	975	1001	1027	1054	1080	1106	1132	1159	1185	1211	1263	1289
6.5	**1582**	1218	1251	1284	1317	1351	1384	1417	1450	1483	1516	1549	1615	1647
7.0	**1984**	1533	1574	1615	1657	1698	1739	1780	1821	1862	1903	1943	2024	2065
7.5	**2437**	1891	1942	1992	2042	2093	2142	2192	2241	2290	2339	2388	2486	2535
8.0	**2954**	2297	2358	2418	2478	2538	2598	2658	2717	2777	2836	2895	3011	3069
8.5	**3501**	2737	2808	2879	2949	3020	3090	3159	3228	3298	3366	3433	3565	3628
9.0	**4025**	3178	3258	3338	3419	3499	3576	3654	3731	3809	3881	3953	4080	4135
9.5	**4326**	3588	3675	3761	3847	3933	4000	4067	4134	4201	4242	4284	4351	4377
10.0	**4452**	3981	4051	4121	4191	4261	4296	4332	4368	4404	4420	4436	4460	4468
10.5	**4488**	4268	4306	4344	4382	4420	4433	4446	4460	4473	4478	4483	4491	4494
11.0	**4499**	4430	4444	4457	4471	4484	4487	4490	4493	4496	4497	4498	4499	4500
11.5	**4500**	4480	4484	4488	4492	4496	4497	4498	4498	4499	4499	4500	4500	4500
12.0	**4500**	4493	4495	4496	4498	4499	4499	4500	4500	4500	4500	4500	4500	4500
12.5	**4500**	4498	4498	4499	4499	4500	4500	4500	4500	4500	4500	4500	4500	4500
13.0	**4500**	4499	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500
13.5	**4500**	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500
14.0	**4500**	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500
14.5	**4500**	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500
15.0	**4500**	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500
15.5	**4500**	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500
16.0	**4500**	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500
16.5	**4500**	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500
17.0	**4493**	4493	4493	4493	4493	4493	4493	4493	4493	4493	4493	4493	4493	4493
17.5	**4440**	4440	4440	4440	4440	4440	4440	4440	4440	4440	4440	4440	4440	4440
18.0	**4303**	4303	4303	4303	4303	4303	4303	4303	4303	4303	4303	4303	4303	4303
18.5	**4116**	4116	4116	4116	4116	4116	4116	4116	4116	4116	4116	4116	4116	4116
19.0	**3921**	3921	3921	3921	3921	3921	3921	3921	3921	3921	3921	3921	3921	3921
19.5	**3715**	3715	3715	3715	3715	3715	3715	3715	3715	3715	3715	3715	3715	3715
20.0	**3495**	3495	3495	3495	3495	3495	3495	3495	3495	3495	3495	3495	3495	3495
20.5	**3269**	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269	3269
21.0	**3047**	3047	3047	3047	3047	3047	3047	3047	3047	3047	3047	3047	3047	3047
21.5	**2836**	2836	2836	2836	2836	2836	2836	2836	2836	2836	2836	2836	2836	2836
22.0	**2636**	2636	2636	2636	2636	2636	2636	2636	2636	2636	2636	2636	2636	2636
22.5	**2440**	2440	2440	2440	2440	2440	2440	2440	2440	2440	2440	2440	2440	2440
23.0	**2248**	2248	2248	2248	2248	2248	2248	2248	2248	2248	2248	2248	2248	2248
23.5	**2070**	2070	2070	2070	2070	2070	2070	2070	2070	2070	2070	2070	2070	2070
24.0	**1939**	1939	1939	1939	1939	1939	1939	1939	1939	1939	1939	1939	1939	1939

Table 6-1: Power curve, Mode PO4500-0S/PO4500

6.1 Ct Values, Power Optimized Mode PO4500-0S/PO4500

Air density kg/m3														
WS [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**	**1.25**	**1.275**
3.0	**0.874**	0.877	0.877	0.877	0.876	0.876	0.876	0.876	0.875	0.875	0.875	0.874	0.874	0.873
3.5	**0.842**	0.845	0.845	0.844	0.843	0.843	0.843	0.842	0.842	0.842	0.842	0.842	0.841	0.841
4.0	**0.828**	0.827	0.827	0.827	0.827	0.828	0.828	0.828	0.828	0.828	0.828	0.828	0.828	0.828
4.5	**0.823**	0.824	0.824	0.824	0.824	0.824	0.824	0.824	0.824	0.824	0.824	0.824	0.823	0.823
5.0	**0.821**	0.823	0.822	0.822	0.822	0.822	0.822	0.822	0.821	0.821	0.821	0.821	0.821	0.821
5.5	**0.819**	0.821	0.821	0.821	0.821	0.821	0.820	0.820	0.820	0.820	0.819	0.819	0.819	0.818
6.0	**0.815**	0.819	0.819	0.819	0.818	0.818	0.818	0.817	0.817	0.816	0.816	0.815	0.815	0.814
6.5	**0.811**	0.816	0.816	0.815	0.815	0.815	0.814	0.813	0.813	0.812	0.812	0.811	0.810	0.809
7.0	**0.805**	0.813	0.813	0.812	0.811	0.811	0.810	0.809	0.809	0.808	0.807	0.806	0.805	0.804
7.5	**0.798**	0.810	0.809	0.808	0.807	0.806	0.805	0.804	0.803	0.802	0.800	0.799	0.797	0.796
8.0	**0.792**	0.803	0.802	0.801	0.800	0.799	0.798	0.797	0.796	0.795	0.794	0.793	0.791	0.790
8.5	**0.760**	0.771	0.770	0.769	0.768	0.767	0.766	0.765	0.764	0.763	0.762	0.761	0.757	0.755
9.0	**0.701**	0.716	0.715	0.714	0.713	0.712	0.711	0.709	0.708	0.707	0.705	0.703	0.693	0.685
9.5	**0.602**	0.657	0.655	0.653	0.652	0.650	0.645	0.640	0.635	0.629	0.620	0.611	0.591	0.579
10.0	**0.503**	0.602	0.596	0.590	0.584	0.578	0.568	0.558	0.548	0.537	0.526	0.514	0.491	0.480
10.5	**0.420**	0.539	0.528	0.518	0.507	0.497	0.486	0.474	0.463	0.451	0.441	0.430	0.411	0.402
11.0	**0.355**	0.470	0.458	0.446	0.434	0.422	0.412	0.402	0.391	0.381	0.372	0.364	0.347	0.340
11.5	**0.305**	0.404	0.393	0.382	0.372	0.361	0.352	0.344	0.335	0.326	0.319	0.312	0.299	0.292
12.0	**0.265**	0.348	0.339	0.330	0.321	0.312	0.305	0.297	0.290	0.283	0.277	0.271	0.260	0.254
12.5	**0.232**	0.303	0.295	0.288	0.280	0.272	0.266	0.260	0.254	0.248	0.242	0.237	0.228	0.223
13.0	**0.205**	0.266	0.259	0.253	0.246	0.240	0.234	0.229	0.224	0.218	0.214	0.210	0.201	0.197
13.5	**0.183**	0.236	0.230	0.224	0.218	0.213	0.208	0.203	0.199	0.194	0.190	0.187	0.179	0.176
14.0	**0.164**	0.210	0.205	0.200	0.195	0.190	0.186	0.182	0.178	0.174	0.170	0.167	0.161	0.158
14.5	**0.147**	0.188	0.184	0.179	0.175	0.170	0.167	0.163	0.160	0.156	0.153	0.150	0.145	0.142
15.0	**0.133**	0.169	0.165	0.161	0.157	0.154	0.150	0.147	0.144	0.141	0.138	0.136	0.131	0.128
15.5	**0.121**	0.153	0.150	0.146	0.143	0.139	0.136	0.134	0.131	0.128	0.126	0.123	0.119	0.117
16.0	**0.110**	0.139	0.136	0.133	0.130	0.127	0.124	0.122	0.119	0.117	0.114	0.112	0.108	0.106
16.5	**0.101**	0.127	0.124	0.121	0.118	0.116	0.113	0.111	0.109	0.107	0.105	0.103	0.099	0.097
17.0	**0.092**	0.116	0.114	0.111	0.108	0.106	0.104	0.102	0.100	0.098	0.096	0.094	0.091	0.089
17.5	**0.085**	0.106	0.104	0.101	0.099	0.097	0.095	0.093	0.091	0.089	0.088	0.086	0.083	0.082
18.0	**0.076**	0.095	0.093	0.091	0.089	0.086	0.085	0.083	0.082	0.080	0.078	0.077	0.074	0.073
18.5	**0.067**	0.084	0.082	0.080	0.078	0.077	0.075	0.074	0.072	0.071	0.069	0.068	0.066	0.065
19.0	**0.059**	0.074	0.072	0.071	0.069	0.067	0.066	0.065	0.064	0.062	0.061	0.060	0.058	0.057
19.5	**0.052**	0.065	0.064	0.062	0.061	0.060	0.058	0.057	0.056	0.055	0.054	0.053	0.052	0.051
20.0	**0.046**	0.057	0.056	0.055	0.054	0.052	0.051	0.051	0.050	0.049	0.048	0.047	0.045	0.045
20.5	**0.041**	0.050	0.049	0.048	0.047	0.046	0.045	0.044	0.044	0.043	0.042	0.041	0.040	0.039
21.0	**0.036**	0.044	0.043	0.042	0.041	0.040	0.040	0.039	0.038	0.037	0.037	0.036	0.035	0.035
21.5	**0.031**	0.039	0.038	0.037	0.036	0.036	0.035	0.034	0.034	0.033	0.032	0.032	0.031	0.030
22.0	**0.028**	0.034	0.033	0.033	0.032	0.031	0.031	0.030	0.030	0.029	0.029	0.028	0.027	0.027
22.5	**0.025**	0.030	0.029	0.029	0.028	0.028	0.027	0.027	0.026	0.026	0.025	0.025	0.024	0.024
23.0	**0.022**	0.026	0.026	0.025	0.025	0.024	0.024	0.024	0.023	0.023	0.023	0.022	0.022	0.021
23.5	**0.019**	0.023	0.023	0.023	0.022	0.022	0.021	0.021	0.021	0.020	0.020	0.020	0.019	0.019
24.0	**0.018**	0.021	0.021	0.020	0.020	0.019	0.019	0.019	0.019	0.018	0.018	0.018	0.017	0.017

Table 6-2: Ct values, PO4500-0S/PO4500

6.2 Sound Curves, Power Optimized Mode PO4500-0S/PO4500

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^3**	
Wind speed at hub height [m/s]	**Sound Power Level at Hub Height [dBA]** **Mode PO4500-0S (Blades without serrated trailing edge, standard)**	**Sound Power Level at Hub Height [dBA]** **Mode PO4500 (Blades with serrated trailing edge, optional)**
3.0	92.4	91.6
4.0	93.3	92.3
5.0	96.8	95.2
6.0	100.6	98.7
7.0	104.2	102.2
8.0	107.3	105.2
9.0	108.4	106.3
10.0	108.4	106.3
11.0	108.4	106.3
12.0	108.4	106.3
13.0	108.4	106.3
14.0	108.4	106.3
15.0	108.4	106.3

Table 6-3: Sound power level, PO4500-0S/PO4500

7 Power Curves, Sound Optimized Mode SO1

Air density [kg/m³]														
WS [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	**94**	58	61	65	68	71	74	78	81	84	87	90	97	100
3.5	**200**	142	147	152	158	163	168	174	179	184	190	195	206	211
4.0	**333**	245	253	261	269	277	285	293	301	309	317	325	341	349
4.5	**496**	372	383	395	406	417	428	440	451	462	474	485	507	518
5.0	**698**	529	544	560	575	591	606	621	637	652	667	683	713	728
5.5	**944**	720	741	761	781	802	822	842	863	883	903	923	964	984
6.0	**1237**	948	975	1001	1027	1054	1080	1106	1132	1159	1185	1211	1263	1289
6.5	**1582**	1218	1251	1284	1317	1351	1384	1417	1450	1483	1516	1549	1615	1647
7.0	**1984**	1533	1574	1615	1656	1698	1739	1780	1821	1862	1902	1943	2024	2065
7.5	**2437**	1891	1941	1992	2042	2092	2142	2192	2241	2291	2339	2388	2486	2535
8.0	**2947**	2293	2353	2414	2474	2534	2593	2652	2712	2771	2830	2888	3005	3063
8.5	**3461**	2709	2778	2848	2918	2987	3056	3124	3193	3261	3328	3394	3524	3587
9.0	**3915**	3123	3201	3280	3358	3437	3510	3584	3658	3731	3793	3854	3964	4012
9.5	**4195**	3533	3614	3694	3774	3855	3912	3970	4027	4085	4122	4158	4218	4241
10.0	**4369**	3934	3997	4061	4125	4189	4223	4256	4290	4324	4339	4354	4377	4386
10.5	**4457**	4235	4271	4308	4345	4381	4395	4409	4422	4436	4443	4450	4461	4465
11.0	**4496**	4420	4433	4446	4459	4473	4477	4482	4487	4492	4493	4495	4497	4497
11.5	**4500**	4480	4484	4488	4492	4496	4497	4497	4498	4499	4499	4500	4500	4500
12.0	**4500**	4493	4495	4496	4498	4499	4499	4500	4500	4500	4500	4500	4500	4500
12.5	**4500**	4498	4498	4499	4499	4500	4500	4500	4500	4500	4500	4500	4500	4500
13.0	**4496**	4490	4490	4491	4492	4492	4493	4493	4494	4494	4495	4495	4496	4497
13.5	**4469**	4456	4457	4458	4459	4460	4462	4463	4464	4465	4467	4468	4470	4472
14.0	**4421**	4403	4405	4406	4407	4408	4410	4412	4413	4415	4417	4419	4423	4425
14.5	**4369**	4353	4354	4356	4357	4358	4359	4361	4362	4364	4366	4367	4371	4373
15.0	**4328**	4316	4317	4318	4319	4320	4321	4322	4323	4324	4325	4327	4329	4331
15.5	**4297**	4286	4287	4288	4289	4290	4291	4292	4293	4294	4295	4296	4298	4299
16.0	**4268**	4255	4256	4257	4258	4259	4261	4262	4263	4264	4266	4267	4269	4271
16.5	**4234**	4214	4216	4218	4219	4221	4223	4225	4226	4228	4230	4232	4235	4237
17.0	**4176**	4143	4146	4149	4152	4155	4158	4161	4164	4167	4170	4173	4179	4182
17.5	**4086**	4037	4041	4046	4050	4054	4059	4063	4068	4073	4077	4082	4091	4096
18.0	**3950**	3882	3888	3894	3900	3906	3912	3918	3925	3931	3937	3943	3956	3962
18.5	**3767**	3697	3703	3709	3715	3721	3727	3734	3740	3747	3753	3760	3774	3781
19.0	**3591**	3534	3538	3543	3547	3552	3557	3563	3568	3573	3579	3585	3597	3603
19.5	**3442**	3402	3405	3409	3412	3415	3419	3423	3426	3430	3434	3438	3446	3451
20.0	**3318**	3297	3298	3300	3302	3304	3306	3308	3310	3312	3314	3316	3321	3323
20.5	**3184**	3176	3177	3177	3178	3179	3179	3180	3181	3182	3182	3183	3185	3185
21.0	**3022**	3020	3020	3020	3020	3021	3021	3021	3021	3021	3022	3022	3022	3022
21.5	**2835**	2835	2835	2835	2835	2835	2835	2835	2835	2835	2835	2835	2835	2835
22.0	**2636**	2636	2636	2636	2636	2636	2636	2636	2636	2636	2636	2636	2636	2636
22.5	**2440**	2440	2440	2440	2440	2440	2440	2440	2440	2440	2440	2440	2440	2440
23.0	**2248**	2248	2248	2248	2248	2248	2248	2248	2248	2248	2248	2248	2248	2248
23.5	**2070**	2070	2070	2070	2070	2070	2070	2070	2070	2070	2070	2070	2070	2070
24.0	**1939**	1939	1939	1939	1939	1939	1939	1939	1939	1939	1939	1939	1939	1939

Table 7-1: Power curve, Mode SO1

7.1 Ct Values, Sound Optimized Mode SO1

Air density kg/m3														
WS [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**	**1.25**	**1.275**
3.0	**0.874**	0.877	0.877	0.877	0.876	0.876	0.876	0.876	0.875	0.875	0.875	0.874	0.874	0.873
3.5	**0.842**	0.845	0.845	0.844	0.843	0.843	0.842	0.842	0.842	0.842	0.842	0.842	0.842	0.842
4.0	**0.828**	0.827	0.827	0.827	0.827	0.828	0.828	0.828	0.828	0.828	0.828	0.828	0.828	0.828
4.5	**0.823**	0.824	0.824	0.824	0.824	0.824	0.824	0.824	0.824	0.824	0.824	0.823	0.823	0.823
5.0	**0.821**	0.823	0.822	0.822	0.822	0.822	0.822	0.822	0.821	0.821	0.821	0.821	0.821	0.820
5.5	**0.819**	0.821	0.821	0.821	0.821	0.821	0.820	0.820	0.820	0.820	0.819	0.819	0.818	0.818
6.0	**0.815**	0.819	0.819	0.819	0.818	0.818	0.818	0.817	0.817	0.816	0.816	0.815	0.814	0.814
6.5	**0.811**	0.816	0.816	0.815	0.815	0.814	0.814	0.813	0.813	0.812	0.812	0.811	0.810	0.809
7.0	**0.805**	0.813	0.813	0.812	0.811	0.811	0.810	0.809	0.808	0.808	0.807	0.806	0.805	0.804
7.5	**0.798**	0.809	0.808	0.807	0.807	0.806	0.805	0.804	0.802	0.801	0.800	0.799	0.797	0.796
8.0	**0.781**	0.791	0.791	0.790	0.789	0.788	0.787	0.786	0.785	0.783	0.783	0.782	0.780	0.779
8.5	**0.728**	0.740	0.739	0.738	0.737	0.736	0.735	0.734	0.733	0.732	0.731	0.729	0.727	0.725
9.0	**0.658**	0.683	0.682	0.681	0.680	0.679	0.677	0.675	0.673	0.672	0.667	0.662	0.651	0.644
9.5	**0.570**	0.635	0.632	0.629	0.627	0.624	0.618	0.611	0.605	0.598	0.589	0.579	0.559	0.548
10.0	**0.487**	0.589	0.582	0.575	0.568	0.562	0.551	0.541	0.531	0.520	0.509	0.498	0.476	0.466
10.5	**0.415**	0.532	0.521	0.511	0.500	0.490	0.479	0.467	0.456	0.445	0.435	0.425	0.406	0.397
11.0	**0.355**	0.469	0.457	0.445	0.433	0.421	0.411	0.401	0.390	0.380	0.372	0.363	0.347	0.339
11.5	**0.305**	0.404	0.393	0.382	0.372	0.361	0.352	0.344	0.335	0.326	0.319	0.312	0.299	0.292
12.0	**0.265**	0.348	0.339	0.330	0.321	0.312	0.305	0.297	0.290	0.283	0.277	0.271	0.260	0.254
12.5	**0.232**	0.303	0.295	0.288	0.280	0.272	0.266	0.260	0.254	0.248	0.242	0.237	0.228	0.223
13.0	**0.205**	0.265	0.259	0.252	0.246	0.239	0.234	0.229	0.223	0.218	0.214	0.209	0.201	0.197
13.5	**0.181**	0.233	0.228	0.222	0.216	0.211	0.206	0.202	0.197	0.193	0.189	0.185	0.178	0.175
14.0	**0.161**	0.205	0.200	0.195	0.191	0.186	0.182	0.178	0.174	0.170	0.167	0.164	0.158	0.155
14.5	**0.143**	0.182	0.177	0.173	0.169	0.165	0.161	0.158	0.155	0.151	0.148	0.145	0.140	0.138
15.0	**0.128**	0.162	0.158	0.155	0.151	0.147	0.144	0.141	0.138	0.135	0.133	0.130	0.125	0.123
15.5	**0.115**	0.146	0.142	0.139	0.136	0.132	0.130	0.127	0.124	0.122	0.120	0.117	0.113	0.111
16.0	**0.104**	0.131	0.128	0.126	0.123	0.120	0.117	0.115	0.113	0.110	0.108	0.106	0.102	0.101
16.5	**0.095**	0.119	0.116	0.114	0.111	0.108	0.106	0.104	0.102	0.100	0.098	0.096	0.093	0.091
17.0	**0.086**	0.107	0.105	0.102	0.100	0.098	0.096	0.094	0.092	0.091	0.089	0.087	0.084	0.083
17.5	**0.078**	0.096	0.094	0.092	0.091	0.089	0.087	0.085	0.084	0.082	0.081	0.079	0.077	0.076
18.0	**0.070**	0.086	0.084	0.082	0.081	0.079	0.078	0.076	0.075	0.073	0.072	0.071	0.069	0.068
18.5	**0.062**	0.076	0.074	0.073	0.071	0.070	0.069	0.067	0.066	0.065	0.064	0.063	0.061	0.060
19.0	**0.055**	0.067	0.066	0.064	0.063	0.062	0.061	0.060	0.059	0.058	0.057	0.056	0.054	0.053
19.5	**0.049**	0.060	0.059	0.058	0.056	0.055	0.054	0.053	0.052	0.051	0.051	0.050	0.048	0.048
20.0	**0.044**	0.054	0.053	0.052	0.051	0.050	0.049	0.048	0.047	0.046	0.046	0.045	0.044	0.043
20.5	**0.040**	0.049	0.048	0.047	0.046	0.045	0.044	0.043	0.043	0.042	0.041	0.040	0.039	0.038
21.0	**0.035**	0.044	0.043	0.042	0.041	0.040	0.039	0.039	0.038	0.037	0.037	0.036	0.035	0.034
21.5	**0.031**	0.039	0.038	0.037	0.036	0.036	0.035	0.034	0.034	0.033	0.032	0.032	0.031	0.030
22.0	**0.028**	0.034	0.033	0.033	0.032	0.031	0.031	0.030	0.030	0.029	0.029	0.028	0.027	0.027
22.5	**0.025**	0.030	0.029	0.029	0.028	0.028	0.027	0.027	0.026	0.026	0.025	0.025	0.024	0.024
23.0	**0.022**	0.026	0.026	0.025	0.025	0.024	0.024	0.024	0.023	0.023	0.023	0.022	0.022	0.021
23.5	**0.019**	0.023	0.023	0.023	0.022	0.022	0.021	0.021	0.021	0.020	0.020	0.020	0.019	0.019
24.0	**0.018**	0.021	0.021	0.020	0.020	0.019	0.019	0.019	0.019	0.018	0.018	0.018	0.017	0.017

Table 7-2: Ct values, SO1

7.2 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^3**
Wind speed at hub height [m/s]	**Sound Power Level at Hub Height [dBA]** **Mode SO1 (Blades with serrated trailing edge)**
3.0	91.9
4.0	92.0
5.0	94.8
6.0	98.2
7.0	101.6
8.0	104.5
9.0	105.0
10.0	105.0
11.0	105.0
12.0	105.0
13.0	105.0
14.0	105.0
15.0	105.0

Table 7-3: Sound power level, SO1

8 Power Curves, Sound Optimized Mode SO2

Air density [kg/m³]														
WS [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	**94**	58	61	65	68	71	74	78	81	84	87	90	97	100
3.5	**200**	142	147	153	158	163	169	174	179	184	190	195	206	211
4.0	**333**	245	253	261	269	277	285	293	301	309	317	325	341	349
4.5	**496**	372	383	395	406	417	428	440	451	462	474	485	507	518
5.0	**698**	529	544	560	575	591	606	621	637	652	667	683	713	728
5.5	**944**	720	741	761	781	802	822	842	863	883	903	923	964	984
6.0	**1237**	948	975	1001	1027	1054	1080	1106	1132	1159	1185	1211	1263	1289
6.5	**1582**	1218	1251	1284	1317	1351	1384	1417	1450	1483	1516	1549	1615	1647
7.0	**1983**	1532	1574	1615	1656	1698	1739	1780	1821	1862	1902	1943	2024	2064
7.5	**2429**	1884	1934	1984	2034	2084	2134	2183	2232	2282	2331	2380	2477	2526
8.0	**2881**	2244	2303	2361	2420	2478	2536	2594	2651	2709	2766	2824	2937	2993
8.5	**3301**	2593	2659	2726	2793	2860	2925	2990	3056	3121	3181	3241	3354	3407
9.0	**3625**	2939	3013	3086	3160	3234	3298	3362	3426	3490	3535	3580	3654	3682
9.5	**3791**	3313	3380	3448	3515	3582	3624	3665	3706	3747	3762	3777	3802	3814
10.0	**3917**	3632	3682	3731	3780	3830	3848	3866	3883	3901	3907	3912	3919	3921
10.5	**4043**	3892	3918	3945	3971	3997	4006	4016	4025	4034	4037	4040	4044	4045
11.0	**4156**	4090	4102	4115	4127	4140	4143	4147	4150	4154	4155	4155	4156	4155
11.5	**4193**	4158	4164	4170	4176	4183	4184	4186	4188	4190	4191	4192	4193	4193
12.0	**4167**	4144	4148	4151	4154	4157	4159	4160	4162	4163	4164	4166	4168	4169
12.5	**4119**	4105	4107	4108	4110	4112	4113	4114	4115	4116	4117	4118	4120	4122
13.0	**4071**	4060	4061	4062	4063	4064	4065	4066	4067	4068	4069	4070	4072	4074
13.5	**4028**	4018	4019	4020	4021	4021	4022	4023	4024	4025	4026	4027	4029	4031
14.0	**3989**	3980	3981	3981	3982	3982	3983	3984	3985	3986	3987	3988	3990	3991
14.5	**3956**	3948	3949	3949	3950	3950	3951	3952	3952	3953	3954	3955	3957	3958
15.0	**3927**	3919	3919	3920	3920	3921	3922	3922	3923	3924	3925	3926	3927	3928
15.5	**3900**	3893	3893	3894	3894	3895	3896	3896	3897	3898	3899	3899	3901	3902
16.0	**3875**	3867	3868	3868	3869	3870	3870	3871	3872	3872	3873	3874	3876	3877
16.5	**3847**	3837	3837	3838	3839	3840	3841	3842	3842	3843	3844	3845	3848	3849
17.0	**3810**	3798	3799	3800	3801	3802	3803	3804	3806	3807	3808	3809	3812	3813
17.5	**3770**	3756	3757	3759	3760	3761	3762	3763	3765	3766	3767	3769	3771	3773
18.0	**3725**	3710	3711	3712	3714	3715	3716	3718	3719	3720	3722	3723	3726	3728
18.5	**3678**	3663	3664	3665	3667	3668	3669	3671	3672	3674	3675	3677	3680	3681
19.0	**3631**	3615	3617	3618	3619	3621	3622	3624	3625	3627	3628	3629	3633	3634
19.5	**3562**	3549	3550	3551	3552	3553	3555	3556	3557	3558	3559	3560	3563	3564
20.0	**3435**	3428	3429	3430	3430	3431	3431	3432	3433	3433	3434	3435	3436	3437
20.5	**3253**	3251	3251	3251	3251	3252	3252	3252	3252	3253	3253	3253	3254	3254
21.0	**3047**	3047	3047	3047	3047	3047	3047	3047	3047	3047	3047	3047	3047	3047
21.5	**2836**	2836	2836	2836	2836	2836	2836	2836	2836	2836	2836	2836	2836	2836
22.0	**2636**	2636	2636	2636	2636	2636	2636	2636	2636	2636	2636	2636	2636	2636
22.5	**2440**	2440	2440	2440	2440	2440	2440	2440	2440	2440	2440	2440	2440	2440
23.0	**2248**	2248	2248	2248	2248	2248	2248	2248	2248	2248	2248	2248	2248	2248
23.5	**2070**	2070	2070	2070	2070	2070	2070	2070	2070	2070	2070	2070	2070	2070
24.0	**1939**	1939	1939	1939	1939	1939	1939	1939	1939	1939	1939	1939	1939	1939

Table 8-1: Power curve, Mode SO2

8.1 Ct Values, Sound Optimized Mode SO2

Air density kg/m3														
WS [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**	**1.25**	**1.275**
3.0	**0.874**	0.877	0.877	0.877	0.876	0.876	0.876	0.875	0.875	0.875	0.875	0.874	0.874	0.873
3.5	**0.842**	0.845	0.845	0.844	0.843	0.843	0.842	0.842	0.842	0.842	0.842	0.842	0.842	0.841
4.0	**0.828**	0.826	0.827	0.827	0.827	0.828	0.828	0.828	0.828	0.828	0.828	0.828	0.828	0.828
4.5	**0.823**	0.824	0.824	0.824	0.824	0.824	0.824	0.824	0.824	0.824	0.824	0.823	0.823	0.823
5.0	**0.821**	0.822	0.822	0.822	0.822	0.822	0.822	0.822	0.821	0.821	0.821	0.821	0.821	0.820
5.5	**0.819**	0.821	0.821	0.821	0.821	0.820	0.820	0.820	0.820	0.820	0.819	0.819	0.818	0.818
6.0	**0.815**	0.819	0.819	0.819	0.818	0.818	0.818	0.817	0.817	0.816	0.816	0.815	0.814	0.814
6.5	**0.811**	0.816	0.816	0.815	0.815	0.814	0.814	0.813	0.813	0.812	0.812	0.811	0.810	0.809
7.0	**0.805**	0.812	0.812	0.811	0.811	0.810	0.809	0.808	0.808	0.807	0.806	0.805	0.804	0.803
7.5	**0.779**	0.788	0.787	0.786	0.785	0.785	0.784	0.783	0.782	0.781	0.780	0.779	0.778	0.777
8.0	**0.719**	0.727	0.727	0.726	0.725	0.724	0.724	0.723	0.722	0.721	0.720	0.720	0.718	0.717
8.5	**0.651**	0.663	0.662	0.661	0.661	0.660	0.659	0.659	0.658	0.657	0.655	0.653	0.647	0.643
9.0	**0.576**	0.608	0.607	0.606	0.605	0.605	0.602	0.599	0.597	0.594	0.588	0.582	0.566	0.557
9.5	**0.493**	0.570	0.567	0.564	0.561	0.557	0.550	0.542	0.534	0.526	0.515	0.504	0.483	0.472
10.0	**0.422**	0.523	0.516	0.509	0.502	0.495	0.484	0.474	0.464	0.453	0.443	0.432	0.412	0.402
10.5	**0.366**	0.473	0.463	0.453	0.443	0.433	0.423	0.413	0.403	0.393	0.384	0.375	0.358	0.350
11.0	**0.322**	0.423	0.413	0.402	0.392	0.381	0.372	0.363	0.354	0.345	0.337	0.330	0.315	0.308
11.5	**0.280**	0.368	0.359	0.349	0.340	0.331	0.323	0.315	0.308	0.300	0.293	0.287	0.275	0.269
12.0	**0.243**	0.317	0.309	0.301	0.293	0.285	0.278	0.272	0.265	0.259	0.254	0.248	0.238	0.233
12.5	**0.211**	0.273	0.267	0.260	0.253	0.246	0.241	0.235	0.230	0.224	0.220	0.215	0.207	0.203
13.0	**0.184**	0.238	0.232	0.226	0.220	0.214	0.210	0.205	0.200	0.196	0.192	0.188	0.181	0.177
13.5	**0.162**	0.209	0.204	0.199	0.194	0.188	0.184	0.180	0.176	0.172	0.169	0.166	0.159	0.156
14.0	**0.144**	0.184	0.180	0.175	0.171	0.167	0.163	0.160	0.156	0.153	0.150	0.147	0.141	0.139
14.5	**0.129**	0.164	0.160	0.156	0.152	0.149	0.145	0.142	0.139	0.136	0.134	0.131	0.126	0.124
15.0	**0.115**	0.146	0.143	0.140	0.136	0.133	0.130	0.128	0.125	0.122	0.120	0.118	0.113	0.111
15.5	**0.104**	0.132	0.129	0.126	0.123	0.120	0.117	0.115	0.113	0.110	0.108	0.106	0.102	0.100
16.0	**0.094**	0.119	0.116	0.114	0.111	0.108	0.106	0.104	0.102	0.100	0.098	0.096	0.093	0.091
16.5	**0.086**	0.108	0.106	0.103	0.101	0.098	0.096	0.095	0.093	0.091	0.089	0.087	0.084	0.083
17.0	**0.078**	0.098	0.096	0.094	0.092	0.089	0.088	0.086	0.084	0.083	0.081	0.080	0.077	0.076
17.5	**0.072**	0.090	0.088	0.086	0.084	0.082	0.080	0.079	0.077	0.076	0.074	0.073	0.071	0.069
18.0	**0.066**	0.082	0.080	0.078	0.076	0.075	0.073	0.072	0.071	0.069	0.068	0.067	0.065	0.063
18.5	**0.060**	0.075	0.073	0.072	0.070	0.068	0.067	0.066	0.065	0.063	0.062	0.061	0.059	0.058
19.0	**0.055**	0.068	0.067	0.065	0.064	0.062	0.061	0.060	0.059	0.058	0.057	0.056	0.054	0.053
19.5	**0.050**	0.062	0.061	0.060	0.058	0.057	0.056	0.055	0.054	0.053	0.052	0.051	0.050	0.049
20.0	**0.045**	0.056	0.055	0.054	0.053	0.052	0.051	0.050	0.049	0.048	0.047	0.046	0.045	0.044
20.5	**0.040**	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
21.0	**0.036**	0.044	0.043	0.042	0.041	0.040	0.040	0.039	0.038	0.037	0.037	0.036	0.035	0.035
21.5	**0.031**	0.039	0.038	0.037	0.036	0.036	0.035	0.034	0.034	0.033	0.032	0.032	0.031	0.030
22.0	**0.028**	0.034	0.033	0.033	0.032	0.031	0.031	0.030	0.030	0.029	0.029	0.028	0.027	0.027
22.5	**0.025**	0.030	0.029	0.029	0.028	0.028	0.027	0.027	0.026	0.026	0.025	0.025	0.024	0.024
23.0	**0.022**	0.026	0.026	0.025	0.025	0.024	0.024	0.024	0.023	0.023	0.023	0.022	0.022	0.021
23.5	**0.019**	0.023	0.023	0.023	0.022	0.022	0.021	0.021	0.021	0.020	0.020	0.020	0.019	0.019
24.0	**0.018**	0.021	0.021	0.020	0.020	0.019	0.019	0.019	0.019	0.018	0.018	0.018	0.017	0.017

Table 8-2: Ct values, SO2

8.2 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^3**
Wind speed at hub height [m/s]	**Sound Power Level at Hub Height [dBA]** **Mode SO2 (Blades with serrated trailing edge)**
3.0	91.9
4.0	92.0
5.0	94.8
6.0	98.2
7.0	101.6
8.0	103.1
9.0	103.3
10.0	103.5
11.0	103.5
12.0	103.5
13.0	103.5
14.0	103.5
15.0	103.5

Table 8-3: Sound power level, SO2

9 Power Curves, Sound Optimized Mode SO3

Air density [kg/m³]														
WS [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	**94**	58	61	65	68	71	74	78	81	84	87	90	97	100
3.5	**200**	142	147	153	158	163	169	174	179	184	190	195	206	211
4.0	**333**	245	253	261	269	277	285	293	301	309	317	325	341	349
4.5	**496**	372	383	395	406	417	428	440	451	462	474	485	507	518
5.0	**698**	529	544	560	575	591	606	621	637	652	667	683	713	728
5.5	**944**	720	741	761	781	802	822	842	863	883	903	923	964	984
6.0	**1237**	948	975	1001	1027	1054	1080	1106	1132	1158	1184	1211	1263	1289
6.5	**1574**	1213	1246	1279	1312	1345	1378	1411	1443	1476	1509	1542	1607	1640
7.0	**1932**	1495	1535	1575	1615	1655	1695	1734	1774	1814	1853	1893	1971	2011
7.5	**2269**	1761	1808	1855	1901	1948	1994	2040	2086	2132	2177	2223	2314	2359
8.0	**2588**	2017	2070	2122	2175	2228	2279	2331	2383	2435	2486	2537	2636	2683
8.5	**2858**	2269	2327	2386	2444	2503	2558	2613	2669	2724	2769	2813	2892	2926
9.0	**3036**	2532	2593	2655	2717	2779	2824	2868	2913	2958	2984	3010	3052	3068
9.5	**3129**	2790	2841	2891	2942	2992	3018	3044	3069	3095	3106	3118	3136	3143
10.0	**3203**	3005	3038	3071	3104	3137	3150	3162	3175	3187	3193	3198	3206	3209
10.5	**3246**	3144	3162	3180	3197	3215	3221	3227	3233	3240	3242	3244	3247	3248
11.0	**3269**	3227	3235	3243	3250	3258	3260	3263	3265	3267	3268	3268	3269	3270
11.5	**3276**	3256	3260	3263	3267	3271	3271	3272	3273	3274	3275	3275	3276	3276
12.0	**3264**	3254	3256	3257	3259	3261	3262	3262	3263	3264	3264	3264	3264	3265
12.5	**3238**	3231	3232	3233	3234	3235	3235	3236	3236	3237	3237	3237	3238	3239
13.0	**3204**	3199	3199	3200	3201	3201	3202	3202	3202	3203	3203	3204	3205	3205
13.5	**3172**	3168	3168	3168	3169	3169	3169	3170	3170	3170	3171	3171	3172	3173
14.0	**3143**	3140	3140	3141	3141	3141	3141	3142	3142	3142	3142	3143	3144	3144
14.5	**3120**	3117	3117	3117	3117	3117	3118	3118	3118	3118	3119	3119	3120	3120
15.0	**3098**	3095	3095	3096	3096	3096	3096	3097	3097	3097	3097	3098	3099	3099
15.5	**3076**	3073	3073	3073	3073	3074	3074	3074	3075	3075	3075	3076	3077	3077
16.0	**3052**	3049	3049	3049	3049	3050	3050	3050	3051	3051	3052	3052	3053	3053
16.5	**3031**	3027	3028	3028	3028	3029	3029	3029	3029	3030	3030	3030	3031	3032
17.0	**3012**	3007	3008	3008	3009	3009	3009	3010	3010	3010	3011	3011	3012	3013
17.5	**2990**	2985	2985	2985	2986	2986	2987	2987	2988	2988	2989	2989	2990	2991
18.0	**2967**	2962	2963	2963	2963	2964	2964	2964	2965	2965	2966	2966	2967	2968
18.5	**2947**	2944	2944	2944	2945	2945	2945	2945	2946	2946	2946	2947	2948	2948
19.0	**2933**	2930	2930	2930	2930	2931	2931	2931	2932	2932	2932	2933	2933	2934
19.5	**2921**	2919	2919	2919	2919	2919	2920	2920	2920	2920	2920	2921	2921	2921
20.0	**2910**	2908	2908	2908	2908	2909	2909	2909	2909	2910	2910	2910	2910	2911
20.5	**2897**	2895	2895	2895	2895	2895	2896	2896	2896	2896	2897	2897	2897	2898
21.0	**2855**	2853	2853	2853	2853	2854	2854	2854	2854	2854	2855	2855	2855	2855
21.5	**2772**	2771	2771	2771	2771	2771	2771	2771	2772	2772	2772	2772	2772	2773
22.0	**2625**	2625	2625	2625	2625	2625	2625	2625	2625	2625	2625	2625	2625	2625
22.5	**2440**	2440	2440	2440	2440	2440	2440	2440	2440	2440	2440	2440	2440	2440
23.0	**2248**	2248	2248	2248	2248	2248	2248	2248	2248	2248	2248	2248	2248	2248
23.5	**2070**	2070	2070	2070	2070	2070	2070	2070	2070	2070	2070	2070	2070	2070
24.0	**1939**	1939	1939	1939	1939	1939	1939	1939	1939	1939	1939	1939	1939	1939

Table 9-1: Power curve, Mode SO3

9.1 Ct Values, Sound Optimized Mode SO3

Air density kg/m3														
WS [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**	**1.25**	**1.275**
3.0	**0.874**	0.877	0.877	0.877	0.876	0.876	0.876	0.875	0.875	0.875	0.875	0.874	0.874	0.873
3.5	**0.842**	0.845	0.845	0.844	0.843	0.843	0.842	0.842	0.842	0.842	0.842	0.842	0.842	0.841
4.0	**0.828**	0.826	0.827	0.827	0.827	0.828	0.828	0.828	0.828	0.828	0.828	0.828	0.828	0.828
4.5	**0.823**	0.824	0.824	0.824	0.824	0.824	0.824	0.824	0.824	0.824	0.824	0.823	0.823	0.823
5.0	**0.821**	0.822	0.822	0.822	0.822	0.822	0.822	0.822	0.821	0.821	0.821	0.821	0.821	0.820
5.5	**0.819**	0.821	0.821	0.821	0.821	0.820	0.820	0.820	0.820	0.820	0.819	0.819	0.818	0.818
6.0	**0.814**	0.818	0.818	0.818	0.817	0.817	0.817	0.816	0.816	0.815	0.815	0.814	0.814	0.813
6.5	**0.789**	0.795	0.794	0.794	0.793	0.793	0.792	0.792	0.791	0.791	0.790	0.790	0.789	0.788
7.0	**0.725**	0.730	0.729	0.729	0.729	0.728	0.728	0.727	0.727	0.726	0.726	0.725	0.724	0.724
7.5	**0.650**	0.654	0.654	0.653	0.653	0.653	0.652	0.652	0.652	0.651	0.651	0.650	0.650	0.649
8.0	**0.585**	0.589	0.589	0.588	0.588	0.588	0.588	0.587	0.587	0.586	0.586	0.585	0.583	0.582
8.5	**0.519**	0.535	0.534	0.534	0.534	0.533	0.532	0.531	0.530	0.529	0.526	0.522	0.514	0.508
9.0	**0.449**	0.491	0.490	0.489	0.488	0.487	0.483	0.478	0.474	0.470	0.463	0.456	0.441	0.433
9.5	**0.383**	0.452	0.448	0.444	0.440	0.436	0.429	0.422	0.415	0.408	0.400	0.391	0.376	0.368
10.0	**0.329**	0.410	0.404	0.397	0.390	0.384	0.376	0.368	0.360	0.352	0.344	0.337	0.322	0.316
10.5	**0.284**	0.364	0.357	0.349	0.341	0.333	0.326	0.318	0.311	0.303	0.297	0.290	0.278	0.272
11.0	**0.245**	0.320	0.312	0.304	0.297	0.289	0.282	0.276	0.269	0.262	0.257	0.251	0.240	0.235
11.5	**0.213**	0.278	0.271	0.264	0.258	0.251	0.245	0.239	0.233	0.228	0.223	0.218	0.209	0.205
12.0	**0.186**	0.242	0.236	0.230	0.224	0.218	0.213	0.208	0.203	0.198	0.194	0.190	0.182	0.179
12.5	**0.163**	0.211	0.206	0.200	0.195	0.190	0.186	0.182	0.177	0.173	0.170	0.166	0.160	0.156
13.0	**0.143**	0.184	0.180	0.175	0.171	0.166	0.163	0.159	0.156	0.152	0.149	0.146	0.140	0.138
13.5	**0.126**	0.163	0.159	0.155	0.151	0.147	0.144	0.141	0.138	0.134	0.132	0.129	0.124	0.122
14.0	**0.113**	0.144	0.141	0.137	0.134	0.131	0.128	0.125	0.122	0.120	0.117	0.115	0.111	0.108
14.5	**0.101**	0.129	0.126	0.123	0.120	0.117	0.114	0.112	0.109	0.107	0.105	0.103	0.099	0.097
15.0	**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	0.087
15.5	**0.082**	0.104	0.102	0.099	0.097	0.095	0.093	0.091	0.089	0.087	0.085	0.084	0.081	0.079
16.0	**0.074**	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
16.5	**0.068**	0.085	0.084	0.082	0.080	0.078	0.076	0.075	0.073	0.072	0.070	0.069	0.067	0.065
17.0	**0.062**	0.078	0.076	0.075	0.073	0.071	0.070	0.068	0.067	0.066	0.064	0.063	0.061	0.060
17.5	**0.057**	0.072	0.070	0.069	0.067	0.065	0.064	0.063	0.062	0.060	0.059	0.058	0.056	0.055
18.0	**0.053**	0.066	0.064	0.063	0.061	0.060	0.059	0.058	0.057	0.055	0.054	0.054	0.052	0.051
18.5	**0.048**	0.060	0.059	0.058	0.057	0.055	0.054	0.053	0.052	0.051	0.050	0.049	0.048	0.047
19.0	**0.045**	0.056	0.055	0.053	0.052	0.051	0.050	0.049	0.048	0.047	0.046	0.046	0.044	0.043
19.5	**0.042**	0.052	0.051	0.049	0.048	0.047	0.046	0.046	0.045	0.044	0.043	0.042	0.041	0.040
20.0	**0.039**	0.048	0.047	0.046	0.045	0.044	0.043	0.042	0.042	0.041	0.040	0.039	0.038	0.038
20.5	**0.036**	0.045	0.044	0.043	0.042	0.041	0.040	0.040	0.039	0.038	0.037	0.037	0.036	0.035
21.0	**0.034**	0.041	0.041	0.040	0.039	0.038	0.037	0.037	0.036	0.035	0.035	0.034	0.033	0.033
21.5	**0.031**	0.038	0.037	0.036	0.036	0.035	0.034	0.034	0.033	0.032	0.032	0.031	0.030	0.030
22.0	**0.028**	0.034	0.033	0.033	0.032	0.031	0.031	0.030	0.030	0.029	0.029	0.028	0.027	0.027
22.5	**0.025**	0.030	0.029	0.029	0.028	0.028	0.027	0.027	0.026	0.026	0.025	0.025	0.024	0.024
23.0	**0.022**	0.026	0.026	0.025	0.025	0.024	0.024	0.024	0.023	0.023	0.023	0.022	0.022	0.021
23.5	**0.019**	0.023	0.023	0.023	0.022	0.022	0.021	0.021	0.021	0.020	0.020	0.020	0.019	0.019
24.0	**0.018**	0.021	0.021	0.020	0.020	0.019	0.019	0.019	0.019	0.018	0.018	0.018	0.017	0.017

Table 9-2: Ct values, SO3

9.2 Sound Curves, Sound Optimized Mode SO3

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^3**
Wind speed at hub height [m/s]	**Sound Power Level at Hub Height [dBA]** **Mode SO3 (Blades with serrated trailing edge)**
3.0	91.9
4.0	92.0
5.0	94.8
6.0	98.2
7.0	100.0
8.0	100.0
9.0	100.0
10.0	100.0
11.0	100.0
12.0	100.0
13.0	100.0
14.0	100.0
15.0	100.0

Table 9-3: Sound power level, SO3

10 Power Curves, Sound Optimized Mode SO12

Air density [kg/m³]														
WS [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	79	47	50	53	56	59	62	65	68	71	73	76	82	85
3.5	169	118	123	127	132	137	141	146	150	155	160	164	174	178
4.0	274	200	207	214	221	227	234	241	248	254	261	268	281	288
4.5	395	295	304	313	322	331	340	349	358	367	376	386	404	412
5.0	583	442	455	468	481	494	506	519	532	545	557	570	595	607
5.5	824	642	660	678	696	714	731	748	765	782	796	810	835	846
6.0	1023	832	855	877	899	922	939	956	974	991	1002	1013	1031	1038
6.5	1276	1036	1064	1090	1118	1144	1167	1189	1212	1234	1248	1262	1285	1294
7.0	1605	1282	1316	1350	1384	1418	1448	1478	1507	1537	1560	1583	1623	1640
7.5	2023	1590	1631	1673	1715	1757	1797	1837	1877	1917	1953	1988	2052	2082
8.0	2429	1902	1951	2001	2050	2100	2149	2197	2246	2295	2340	2384	2467	2505
8.5	2741	2182	2239	2295	2351	2407	2460	2512	2565	2618	2659	2700	2771	2801
9.0	2946	2467	2526	2586	2645	2705	2747	2789	2832	2874	2898	2922	2960	2974
9.5	3070	2746	2795	2843	2891	2939	2964	2988	3012	3036	3048	3059	3076	3083
10.0	3164	2974	3005	3037	3068	3100	3112	3124	3136	3148	3153	3158	3166	3169
10.5	3210	3112	3129	3146	3162	3179	3185	3191	3197	3203	3205	3207	3210	3211
11.0	3227	3187	3194	3202	3209	3216	3218	3221	3223	3225	3226	3226	3228	3228
11.5	3222	3203	3207	3210	3214	3217	3218	3219	3220	3221	3222	3222	3223	3223
12.0	3208	3198	3200	3202	3203	3205	3206	3206	3207	3208	3208	3208	3208	3209
12.5	3187	3180	3181	3182	3183	3184	3185	3185	3185	3186	3186	3186	3187	3188
13.0	3158	3152	3153	3153	3154	3155	3155	3156	3156	3157	3157	3158	3159	3160
13.5	3125	3119	3120	3120	3121	3121	3122	3122	3123	3123	3124	3124	3126	3126
14.0	3092	3087	3087	3087	3088	3088	3088	3089	3089	3090	3090	3091	3092	3093
14.5	3065	3062	3062	3062	3062	3062	3063	3063	3064	3064	3064	3065	3065	3066
15.0	3050	3048	3048	3048	3048	3049	3049	3049	3049	3050	3050	3050	3050	3051
15.5	3038	3035	3035	3035	3035	3036	3036	3036	3037	3037	3037	3037	3038	3038
16.0	3022	3019	3019	3019	3019	3020	3020	3020	3021	3021	3021	3022	3022	3023
16.5	3006	3004	3004	3004	3004	3004	3005	3005	3005	3006	3006	3006	3007	3007
17.0	2993	2990	2990	2990	2990	2991	2991	2991	2992	2992	2992	2993	2993	2994
17.5	2978	2973	2974	2974	2975	2975	2975	2976	2976	2976	2977	2977	2978	2978
18.0	2960	2954	2955	2955	2956	2956	2957	2957	2958	2958	2959	2959	2960	2961
18.5	2939	2934	2934	2935	2935	2936	2936	2937	2937	2938	2938	2939	2940	2940
19.0	2919	2913	2914	2914	2914	2915	2916	2916	2917	2917	2918	2918	2919	2920
19.5	2895	2889	2889	2890	2891	2891	2892	2892	2893	2894	2894	2895	2896	2897
20.0	2868	2860	2860	2861	2862	2862	2863	2864	2865	2866	2866	2867	2868	2869
20.5	2831	2820	2821	2822	2823	2824	2825	2826	2827	2828	2829	2830	2832	2833
21.0	2783	2770	2771	2772	2773	2774	2776	2777	2778	2779	2780	2782	2784	2785
21.5	2713	2701	2702	2703	2704	2705	2706	2707	2708	2710	2711	2712	2714	2714
22.0	2595	2588	2589	2590	2590	2591	2592	2592	2593	2594	2594	2595	2596	2597
22.5	2434	2432	2432	2433	2433	2433	2433	2433	2434	2434	2434	2434	2434	2434
23.0	2248	2248	2248	2248	2248	2248	2248	2248	2248	2248	2248	2248	2248	2248
23.5	2070	2070	2070	2070	2070	2070	2070	2070	2070	2070	2070	2070	2070	2070
24.0	1939	1939	1939	1939	1939	1939	1939	1939	1939	1939	1939	1939	1939	1939

Table 10-1: Power curve, SO12

10.1 Ct Values, Sound Optimized Mode SO12

Air density kg/m3														
WS [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**	**1.25**	**1.275**
3.0	**0.676**	0.680	0.679	0.679	0.679	0.678	0.678	0.678	0.677	0.677	0.676	0.676	0.675	0.675
3.5	**0.622**	0.625	0.624	0.624	0.624	0.623	0.623	0.623	0.623	0.623	0.622	0.622	0.622	0.621
4.0	**0.574**	0.576	0.576	0.576	0.575	0.575	0.575	0.575	0.575	0.575	0.574	0.574	0.574	0.574
4.5	**0.531**	0.533	0.533	0.533	0.533	0.533	0.532	0.532	0.532	0.532	0.532	0.531	0.531	0.531
5.0	**0.556**	0.559	0.559	0.559	0.558	0.558	0.558	0.558	0.557	0.557	0.557	0.556	0.555	0.554
5.5	**0.590**	0.608	0.608	0.607	0.607	0.607	0.606	0.604	0.603	0.602	0.598	0.594	0.584	0.578
6.0	**0.547**	0.592	0.592	0.591	0.590	0.590	0.585	0.580	0.576	0.571	0.563	0.555	0.537	0.528
6.5	**0.525**	0.565	0.565	0.564	0.563	0.562	0.558	0.555	0.551	0.548	0.540	0.533	0.516	0.507
7.0	**0.524**	0.550	0.550	0.549	0.549	0.549	0.546	0.544	0.541	0.539	0.534	0.529	0.518	0.511
7.5	**0.539**	0.552	0.552	0.551	0.551	0.550	0.550	0.549	0.548	0.547	0.544	0.542	0.535	0.531
8.0	**0.531**	0.539	0.538	0.538	0.538	0.538	0.537	0.537	0.536	0.536	0.534	0.533	0.528	0.525
8.5	**0.490**	0.507	0.506	0.506	0.506	0.505	0.504	0.503	0.502	0.501	0.497	0.494	0.484	0.479
9.0	**0.432**	0.475	0.473	0.472	0.471	0.470	0.466	0.461	0.457	0.452	0.446	0.439	0.424	0.416
9.5	**0.374**	0.443	0.439	0.435	0.431	0.426	0.419	0.412	0.405	0.398	0.390	0.382	0.367	0.359
10.0	**0.324**	0.405	0.398	0.391	0.385	0.378	0.370	0.362	0.354	0.346	0.339	0.332	0.318	0.311
10.5	**0.280**	0.360	0.352	0.344	0.337	0.329	0.321	0.314	0.307	0.300	0.293	0.287	0.274	0.268
11.0	**0.242**	0.315	0.308	0.300	0.292	0.285	0.278	0.272	0.265	0.259	0.253	0.248	0.237	0.232
11.5	**0.210**	0.273	0.267	0.260	0.253	0.246	0.241	0.235	0.229	0.224	0.219	0.214	0.206	0.201
12.0	**0.183**	0.238	0.232	0.226	0.220	0.214	0.209	0.204	0.200	0.195	0.191	0.187	0.179	0.176
12.5	**0.160**	0.207	0.202	0.197	0.192	0.187	0.183	0.179	0.175	0.170	0.167	0.164	0.157	0.154
13.0	**0.141**	0.182	0.177	0.173	0.168	0.164	0.160	0.157	0.153	0.150	0.147	0.144	0.138	0.136
13.5	**0.125**	0.160	0.156	0.152	0.149	0.145	0.142	0.139	0.135	0.132	0.130	0.127	0.122	0.120
14.0	**0.111**	0.142	0.138	0.135	0.132	0.128	0.126	0.123	0.120	0.118	0.115	0.113	0.109	0.107
14.5	**0.099**	0.126	0.124	0.121	0.118	0.115	0.112	0.110	0.108	0.105	0.103	0.101	0.097	0.096
15.0	**0.089**	0.114	0.111	0.108	0.106	0.103	0.101	0.099	0.097	0.095	0.093	0.091	0.088	0.086
15.5	**0.081**	0.103	0.100	0.098	0.096	0.093	0.092	0.090	0.088	0.086	0.084	0.083	0.080	0.078
16.0	**0.074**	0.093	0.091	0.089	0.087	0.085	0.083	0.081	0.080	0.078	0.077	0.075	0.072	0.071
16.5	**0.067**	0.085	0.083	0.081	0.079	0.077	0.076	0.074	0.073	0.071	0.070	0.069	0.066	0.065
17.0	**0.062**	0.078	0.076	0.074	0.072	0.071	0.069	0.068	0.067	0.065	0.064	0.063	0.061	0.060
17.5	**0.057**	0.071	0.070	0.068	0.067	0.065	0.064	0.063	0.061	0.060	0.059	0.058	0.056	0.055
18.0	**0.052**	0.066	0.064	0.063	0.061	0.060	0.059	0.058	0.056	0.055	0.054	0.053	0.052	0.051
18.5	**0.048**	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
19.0	**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
19.5	**0.041**	0.051	0.050	0.049	0.048	0.047	0.046	0.045	0.044	0.043	0.043	0.042	0.041	0.040
20.0	**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
20.5	**0.036**	0.044	0.043	0.042	0.041	0.040	0.039	0.039	0.038	0.037	0.037	0.036	0.035	0.034
21.0	**0.033**	0.040	0.040	0.039	0.038	0.037	0.036	0.036	0.035	0.035	0.034	0.033	0.032	0.032
21.5	**0.030**	0.037	0.036	0.036	0.035	0.034	0.034	0.033	0.032	0.032	0.031	0.031	0.030	0.029
22.0	**0.027**	0.034	0.033	0.032	0.032	0.031	0.030	0.030	0.029	0.029	0.028	0.028	0.027	0.027
22.5	**0.025**	0.030	0.029	0.029	0.028	0.028	0.027	0.027	0.026	0.026	0.025	0.025	0.024	0.024
23.0	**0.022**	0.026	0.026	0.025	0.025	0.024	0.024	0.024	0.023	0.023	0.023	0.022	0.022	0.021
23.5	**0.019**	0.023	0.023	0.023	0.022	0.022	0.021	0.021	0.021	0.020	0.020	0.020	0.019	0.019
24.0	**0.018**	0.021	0.021	0.020	0.020	0.019	0.019	0.019	0.019	0.018	0.018	0.018	0.017	0.017

Table 10-2: Ct values, SO12

10.2 Sound Curves, Sound Optimized Mode SO12

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^3**
Wind speed at hub height [m/s]	**Sound Power Level at Hub Height [dBA]** **Mode SO3 (Blades with serrated trailing edge)**
3.0	91.9
4.0	92.0
5.0	92.7
6.0	94.5
7.0	96.7
8.0	98.7
9.0	99.5
10.0	99.7
11.0	99.9
12.0	100.0
13.0	100.0
14.0	100.0
15.0	100.0

Table 10-3: Sound power level, SO12

11 Power Curves, Sound Optimized Mode SO11

Air density [kg/m³]														
WS [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	79	47	50	53	56	59	62	65	68	71	73	76	82	85
3.5	169	118	123	127	132	137	141	146	150	155	160	164	174	178
4.0	275	201	208	214	221	228	234	241	248	255	261	268	281	288
4.5	397	297	306	316	325	334	343	352	362	371	380	388	406	415
5.0	541	446	456	466	477	487	495	503	512	520	527	534	547	552
5.5	742	649	661	673	685	697	705	713	720	728	733	737	745	748
6.0	994	840	859	879	899	919	932	946	959	972	980	987	998	1002
6.5	1175	1016	1039	1061	1083	1106	1119	1132	1145	1158	1164	1169	1177	1180
7.0	1372	1202	1227	1251	1275	1299	1313	1326	1340	1354	1360	1366	1375	1378
7.5	1652	1423	1454	1485	1516	1547	1566	1586	1605	1624	1633	1642	1656	1661
8.0	1949	1661	1699	1738	1776	1814	1839	1863	1888	1912	1925	1937	1955	1961
8.5	2261	1912	1956	2002	2046	2092	2122	2152	2183	2213	2229	2245	2270	2278
9.0	2587	2199	2251	2303	2355	2407	2440	2473	2506	2538	2555	2571	2595	2602
9.5	2808	2509	2555	2600	2645	2691	2713	2735	2757	2780	2789	2799	2813	2817
10.0	2944	2757	2788	2820	2851	2882	2894	2906	2917	2929	2934	2939	2946	2949
10.5	3017	2920	2936	2953	2970	2987	2993	2999	3005	3011	3013	3015	3017	3018
11.0	3071	3031	3039	3046	3054	3061	3063	3065	3067	3069	3070	3070	3071	3071
11.5	3114	3096	3100	3103	3107	3110	3111	3112	3113	3114	3114	3114	3114	3114
12.0	3125	3115	3117	3119	3120	3122	3123	3123	3124	3124	3124	3125	3125	3125
12.5	3104	3096	3097	3098	3099	3100	3101	3101	3102	3102	3103	3103	3104	3104
13.0	3058	3052	3053	3054	3054	3055	3056	3056	3056	3057	3057	3058	3059	3060
13.5	3017	3013	3013	3013	3014	3014	3014	3015	3015	3016	3016	3016	3017	3018
14.0	2988	2986	2987	2987	2987	2987	2987	2987	2988	2988	2988	2988	2989	2989
14.5	2972	2970	2970	2970	2971	2971	2971	2971	2971	2972	2972	2972	2972	2973
15.0	2950	2947	2947	2947	2948	2948	2948	2948	2948	2949	2949	2949	2950	2951
15.5	2925	2922	2922	2922	2923	2923	2923	2924	2924	2924	2924	2925	2926	2926
16.0	2898	2894	2895	2895	2895	2896	2896	2896	2897	2897	2898	2898	2899	2900
16.5	2871	2866	2867	2867	2867	2868	2868	2868	2869	2869	2870	2870	2871	2872
17.0	2843	2838	2838	2839	2839	2840	2840	2840	2841	2841	2842	2842	2844	2844
17.5	2817	2813	2813	2813	2814	2814	2814	2815	2815	2816	2816	2817	2818	2818
18.0	2792	2788	2788	2789	2789	2790	2790	2790	2791	2791	2791	2792	2793	2793
18.5	2767	2762	2763	2763	2764	2764	2765	2765	2766	2766	2766	2767	2768	2768
19.0	2744	2739	2740	2740	2740	2741	2741	2742	2742	2742	2743	2743	2744	2744
19.5	2724	2721	2721	2721	2722	2722	2722	2722	2723	2723	2723	2724	2724	2724
20.0	2712	2711	2711	2711	2711	2712	2712	2712	2712	2712	2712	2712	2712	2712
20.5	2710	2712	2711	2711	2711	2711	2711	2711	2711	2711	2711	2710	2710	2710
21.0	2709	2711	2711	2711	2711	2710	2710	2710	2710	2710	2710	2709	2709	2708
21.5	2678	2680	2680	2680	2680	2680	2679	2679	2679	2678	2678	2678	2678	2677
22.0	2585	2586	2586	2586	2586	2586	2586	2586	2586	2586	2586	2585	2585	2585
22.5	2434	2434	2434	2434	2434	2434	2434	2434	2434	2434	2434	2434	2434	2434
23.0	2248	2248	2248	2248	2248	2248	2248	2248	2248	2248	2248	2248	2248	2248
23.5	2070	2070	2070	2070	2070	2070	2070	2070	2070	2070	2070	2070	2070	2070
24.0	1939	1939	1939	1939	1939	1939	1939	1939	1939	1939	1939	1939	1939	1939

Table 11-1: Power curve, SO11

11.1 Ct Values, Sound Optimized Mode SO11

Air density kg/m3														
WS [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**	**1.25**	**1.275**
3.0	0.676	0.680	0.679	0.679	0.679	0.678	0.678	0.678	0.677	0.677	0.676	0.676	0.675	0.675
3.5	0.622	0.625	0.624	0.624	0.624	0.624	0.623	0.623	0.623	0.623	0.622	0.622	0.622	0.621
4.0	0.576	0.578	0.577	0.577	0.577	0.577	0.577	0.577	0.576	0.576	0.576	0.576	0.576	0.575
4.5	0.539	0.542	0.542	0.541	0.541	0.541	0.541	0.541	0.541	0.540	0.540	0.539	0.538	0.537
5.0	0.510	0.569	0.564	0.560	0.555	0.551	0.545	0.539	0.533	0.528	0.522	0.516	0.503	0.497
5.5	0.517	0.620	0.613	0.605	0.598	0.590	0.580	0.570	0.559	0.549	0.538	0.527	0.506	0.495
6.0	0.528	0.602	0.599	0.596	0.593	0.589	0.582	0.574	0.567	0.559	0.549	0.539	0.517	0.506
6.5	0.474	0.552	0.548	0.545	0.541	0.538	0.530	0.522	0.514	0.506	0.495	0.485	0.464	0.453
7.0	0.430	0.506	0.501	0.497	0.493	0.489	0.481	0.473	0.466	0.458	0.449	0.439	0.421	0.412
7.5	0.416	0.478	0.475	0.472	0.469	0.466	0.459	0.453	0.447	0.441	0.432	0.424	0.407	0.399
8.0	0.401	0.453	0.451	0.449	0.447	0.445	0.439	0.434	0.429	0.424	0.416	0.409	0.393	0.385
8.5	0.385	0.429	0.428	0.426	0.425	0.423	0.419	0.414	0.410	0.405	0.399	0.392	0.378	0.370
9.0	0.369	0.412	0.411	0.410	0.408	0.407	0.402	0.398	0.393	0.389	0.382	0.375	0.361	0.354
9.5	0.337	0.398	0.394	0.390	0.387	0.383	0.377	0.371	0.364	0.358	0.351	0.344	0.330	0.323
10.0	0.299	0.371	0.365	0.359	0.353	0.348	0.340	0.333	0.326	0.319	0.312	0.306	0.293	0.287
10.5	0.261	0.335	0.328	0.321	0.314	0.307	0.300	0.293	0.286	0.280	0.273	0.267	0.256	0.251
11.0	0.229	0.298	0.291	0.284	0.277	0.270	0.264	0.257	0.251	0.245	0.240	0.234	0.224	0.220
11.5	0.202	0.264	0.257	0.250	0.244	0.237	0.232	0.227	0.221	0.216	0.211	0.207	0.198	0.194
12.0	0.178	0.231	0.225	0.220	0.214	0.208	0.204	0.199	0.194	0.190	0.186	0.182	0.174	0.171
12.5	0.156	0.202	0.197	0.192	0.187	0.182	0.178	0.174	0.170	0.166	0.163	0.159	0.153	0.150
13.0	0.136	0.176	0.172	0.167	0.163	0.159	0.155	0.152	0.148	0.145	0.142	0.139	0.134	0.131
13.5	0.120	0.155	0.151	0.147	0.144	0.140	0.137	0.134	0.131	0.128	0.125	0.123	0.118	0.116
14.0	0.107	0.137	0.134	0.131	0.127	0.124	0.122	0.119	0.116	0.114	0.111	0.109	0.105	0.103
14.5	0.096	0.123	0.120	0.117	0.114	0.111	0.109	0.107	0.104	0.102	0.100	0.098	0.094	0.093
15.0	0.086	0.110	0.108	0.105	0.102	0.100	0.098	0.096	0.094	0.092	0.090	0.088	0.085	0.083
15.5	0.078	0.099	0.097	0.095	0.092	0.090	0.088	0.086	0.085	0.083	0.081	0.080	0.077	0.075
16.0	0.071	0.090	0.088	0.086	0.084	0.082	0.080	0.078	0.077	0.075	0.074	0.072	0.070	0.068
16.5	0.064	0.081	0.079	0.078	0.076	0.074	0.072	0.071	0.070	0.068	0.067	0.066	0.063	0.062
17.0	0.059	0.074	0.072	0.071	0.069	0.067	0.066	0.065	0.063	0.062	0.061	0.060	0.058	0.057
17.5	0.054	0.068	0.066	0.065	0.063	0.062	0.061	0.059	0.058	0.057	0.056	0.055	0.053	0.052
18.0	0.050	0.062	0.061	0.059	0.058	0.057	0.056	0.055	0.053	0.052	0.051	0.051	0.049	0.048
18.5	0.046	0.057	0.056	0.055	0.053	0.052	0.051	0.050	0.049	0.048	0.047	0.047	0.045	0.044
19.0	0.042	0.052	0.051	0.050	0.049	0.048	0.047	0.046	0.045	0.044	0.044	0.043	0.041	0.041
19.5	0.039	0.048	0.047	0.046	0.045	0.044	0.044	0.043	0.042	0.041	0.040	0.040	0.038	0.038
20.0	0.036	0.045	0.044	0.043	0.042	0.041	0.041	0.040	0.039	0.038	0.038	0.037	0.036	0.035
20.5	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
21.0	0.032	0.039	0.039	0.038	0.037	0.036	0.036	0.035	0.034	0.034	0.033	0.033	0.032	0.031
21.5	0.030	0.037	0.036	0.035	0.034	0.034	0.033	0.033	0.032	0.031	0.031	0.030	0.029	0.029
22.0	0.027	0.033	0.033	0.032	0.031	0.031	0.030	0.030	0.029	0.029	0.028	0.028	0.027	0.027
22.5	0.025	0.030	0.029	0.029	0.028	0.028	0.027	0.027	0.026	0.026	0.025	0.025	0.024	0.024
23.0	0.022	0.026	0.026	0.025	0.025	0.024	0.024	0.024	0.023	0.023	0.023	0.022	0.022	0.021
23.5	0.019	0.023	0.023	0.023	0.022	0.022	0.021	0.021	0.021	0.020	0.020	0.020	0.019	0.019
24.0	0.018	0.021	0.021	0.020	0.020	0.019	0.019	0.019	0.019	0.018	0.018	0.018	0.017	0.017

Table 11-2: Ct values, SO11

11.2 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^3**
Wind speed at hub height [m/s]	**Sound Power Level at Hub Height [dBA]** **Mode SO3 (Blades with serrated trailing edge)**
3.0	91.9
4.0	92.0
5.0	92.9
6.0	94.4
7.0	95.5
8.0	96.8
9.0	98.0
10.0	98.9
11.0	99.1
12.0	99.2
13.0	99.2
14.0	99.2
15.0	99.2

Table 11-3: Sound power level, SO11

12 Power Curves, Sound Optimized Mode SO13

Air density [kg/m³]														
WS [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	79	47	50	53	56	59	62	65	68	71	73	76	82	85
3.5	169	118	123	127	132	137	141	146	150	155	160	164	174	178
4.0	274	200	207	213	220	227	234	240	247	254	260	267	280	287
4.5	381	289	298	307	316	325	333	341	350	358	366	374	388	395
5.0	439	350	360	370	380	391	399	407	415	423	429	434	442	444
5.5	413	323	332	342	351	360	368	376	385	393	400	406	418	423
6.0	415	332	341	350	359	368	375	383	390	398	404	409	419	424
6.5	441	402	408	413	418	423	426	429	432	435	437	439	442	443
7.0	464	460	461	462	463	463	464	464	464	464	464	464	464	463
7.5	685	693	693	693	692	692	691	690	689	689	687	686	684	683
8.0	1109	1105	1107	1109	1112	1114	1114	1113	1113	1113	1112	1110	1108	1106
8.5	1578	1531	1541	1552	1562	1572	1574	1576	1578	1580	1580	1579	1577	1576
9.0	1923	1852	1867	1881	1895	1909	1912	1916	1919	1923	1923	1923	1922	1921
9.5	2134	2064	2078	2091	2104	2117	2121	2125	2128	2132	2133	2134	2134	2133
10.0	2310	2252	2263	2274	2286	2297	2300	2303	2305	2308	2309	2309	2310	2309
10.5	2450	2407	2416	2424	2433	2442	2443	2445	2447	2449	2449	2450	2449	2449
11.0	2564	2534	2539	2545	2551	2556	2558	2559	2561	2562	2563	2563	2563	2563
11.5	2616	2598	2602	2605	2608	2611	2612	2613	2614	2615	2615	2616	2616	2616
12.0	2586	2576	2577	2579	2580	2582	2582	2583	2584	2584	2585	2585	2586	2586
12.5	2519	2513	2514	2515	2515	2516	2516	2517	2517	2518	2518	2518	2519	2520
13.0	2464	2460	2460	2461	2461	2462	2462	2462	2462	2462	2463	2463	2464	2465
13.5	2405	2401	2401	2401	2401	2402	2402	2402	2403	2404	2404	2405	2406	2406
14.0	2331	2325	2325	2325	2326	2326	2327	2327	2328	2328	2329	2330	2332	2332
14.5	2249	2243	2243	2244	2244	2244	2245	2246	2246	2247	2248	2248	2250	2250
15.0	2190	2183	2184	2184	2185	2185	2186	2186	2187	2188	2189	2189	2191	2192
15.5	2123	2114	2114	2115	2116	2116	2117	2118	2119	2120	2121	2122	2124	2125
16.0	2047	2038	2038	2039	2040	2041	2042	2042	2043	2044	2045	2046	2048	2050
16.5	1984	1977	1977	1978	1978	1979	1979	1980	1981	1981	1982	1983	1985	1986
17.0	1934	1928	1928	1929	1929	1930	1930	1931	1932	1932	1933	1934	1935	1936
17.5	1876	1867	1868	1868	1869	1870	1871	1872	1873	1874	1874	1875	1877	1878
18.0	1812	1804	1805	1806	1806	1807	1808	1808	1809	1810	1811	1812	1813	1814
18.5	1754	1748	1748	1748	1749	1749	1750	1750	1751	1752	1752	1753	1754	1755
19.0	1706	1700	1700	1701	1701	1702	1702	1703	1704	1704	1705	1706	1707	1708
19.5	1663	1658	1658	1658	1659	1659	1660	1660	1661	1662	1662	1663	1664	1664
20.0	1628	1622	1622	1623	1623	1624	1624	1625	1625	1626	1626	1627	1628	1629
20.5	1594	1588	1588	1589	1590	1590	1591	1591	1592	1592	1593	1593	1594	1595
21.0	1560	1554	1555	1555	1556	1556	1557	1557	1558	1558	1559	1559	1561	1561
21.5	1526	1520	1521	1521	1522	1522	1523	1524	1524	1524	1525	1526	1526	1527
22.0	1492	1486	1487	1488	1488	1489	1489	1490	1490	1490	1491	1491	1492	1492
22.5	1459	1453	1454	1454	1455	1455	1456	1456	1457	1458	1458	1459	1460	1460
23.0	1422	1416	1417	1417	1418	1418	1419	1419	1420	1420	1421	1422	1423	1423
23.5	1387	1381	1382	1382	1383	1384	1384	1385	1385	1386	1386	1387	1388	1388
24.0	1358	1352	1353	1354	1354	1354	1355	1356	1356	1356	1357	1358	1359	1359

Table 12-1: Power curve, SO13-0S/SO13

12.1 Ct Values, Sound Optimized Mode SO13

Air density kg/m3														
WS [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**	**1.25**	**1.275**
3.0	**0.676**	0.680	0.679	0.679	0.679	0.678	0.678	0.678	0.677	0.677	0.676	0.676	0.675	0.675
3.5	**0.622**	0.624	0.624	0.624	0.624	0.623	0.623	0.623	0.623	0.623	0.622	0.622	0.622	0.621
4.0	**0.571**	0.573	0.573	0.573	0.573	0.572	0.572	0.572	0.572	0.572	0.572	0.572	0.571	0.571
4.5	**0.509**	0.518	0.518	0.518	0.517	0.517	0.516	0.515	0.515	0.514	0.512	0.511	0.507	0.504
5.0	**0.402**	0.427	0.427	0.427	0.426	0.426	0.423	0.421	0.419	0.416	0.411	0.407	0.395	0.389
5.5	**0.274**	0.286	0.286	0.285	0.284	0.284	0.283	0.282	0.281	0.280	0.278	0.276	0.271	0.269
6.0	**0.207**	0.219	0.219	0.218	0.217	0.217	0.216	0.215	0.214	0.212	0.211	0.209	0.205	0.203
6.5	**0.172**	0.202	0.200	0.197	0.194	0.192	0.189	0.186	0.183	0.180	0.177	0.174	0.169	0.166
7.0	**0.144**	0.182	0.178	0.174	0.170	0.166	0.163	0.160	0.156	0.153	0.150	0.147	0.141	0.139
7.5	**0.166**	0.216	0.211	0.206	0.200	0.195	0.190	0.186	0.182	0.177	0.173	0.170	0.162	0.159
8.0	**0.216**	0.283	0.276	0.270	0.263	0.256	0.250	0.244	0.238	0.232	0.227	0.221	0.212	0.207
8.5	**0.257**	0.331	0.324	0.317	0.310	0.303	0.296	0.289	0.282	0.275	0.269	0.263	0.251	0.245
9.0	**0.263**	0.338	0.331	0.324	0.318	0.311	0.304	0.297	0.290	0.283	0.276	0.270	0.258	0.252
9.5	**0.248**	0.319	0.312	0.305	0.299	0.292	0.286	0.279	0.272	0.266	0.260	0.254	0.243	0.238
10.0	**0.229**	0.296	0.289	0.283	0.276	0.270	0.264	0.258	0.251	0.245	0.240	0.235	0.224	0.220
10.5	**0.209**	0.271	0.265	0.259	0.252	0.246	0.240	0.235	0.229	0.224	0.219	0.214	0.205	0.200
11.0	**0.190**	0.246	0.240	0.235	0.229	0.223	0.218	0.213	0.208	0.203	0.198	0.194	0.186	0.182
11.5	**0.169**	0.220	0.214	0.209	0.203	0.198	0.194	0.189	0.185	0.180	0.176	0.173	0.166	0.162
12.0	**0.147**	0.190	0.186	0.181	0.176	0.172	0.168	0.164	0.160	0.156	0.153	0.150	0.144	0.141
12.5	**0.126**	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
13.0	**0.110**	0.142	0.138	0.135	0.131	0.128	0.125	0.123	0.120	0.117	0.115	0.112	0.108	0.106
13.5	**0.096**	0.124	0.121	0.118	0.115	0.112	0.109	0.107	0.105	0.102	0.100	0.098	0.095	0.093
14.0	**0.084**	0.107	0.105	0.102	0.100	0.097	0.095	0.093	0.091	0.089	0.088	0.086	0.083	0.081
14.5	**0.074**	0.093	0.091	0.089	0.087	0.085	0.083	0.081	0.080	0.078	0.077	0.075	0.072	0.071
15.0	**0.065**	0.082	0.081	0.079	0.077	0.075	0.074	0.072	0.071	0.069	0.068	0.067	0.064	0.063
15.5	**0.058**	0.073	0.071	0.070	0.068	0.066	0.065	0.064	0.062	0.061	0.060	0.059	0.057	0.056
16.0	**0.051**	0.064	0.063	0.061	0.060	0.059	0.058	0.056	0.055	0.054	0.053	0.052	0.051	0.050
16.5	**0.046**	0.057	0.056	0.055	0.054	0.052	0.051	0.050	0.049	0.048	0.048	0.047	0.045	0.044
17.0	**0.041**	0.051	0.050	0.049	0.048	0.047	0.046	0.045	0.045	0.044	0.043	0.042	0.041	0.040
17.5	**0.038**	0.046	0.045	0.045	0.044	0.043	0.042	0.041	0.040	0.040	0.039	0.038	0.037	0.036
18.0	**0.034**	0.042	0.041	0.040	0.039	0.038	0.038	0.037	0.036	0.036	0.035	0.035	0.033	0.033
18.5	**0.031**	0.038	0.037	0.036	0.035	0.035	0.034	0.033	0.033	0.032	0.032	0.031	0.030	0.030
19.0	**0.028**	0.034	0.033	0.033	0.032	0.032	0.031	0.030	0.030	0.029	0.029	0.028	0.028	0.027
19.5	**0.026**	0.031	0.031	0.030	0.029	0.029	0.028	0.028	0.027	0.027	0.026	0.026	0.025	0.025
20.0	**0.024**	0.029	0.028	0.028	0.027	0.027	0.026	0.026	0.025	0.025	0.024	0.024	0.023	0.023
20.5	**0.022**	0.026	0.026	0.026	0.025	0.025	0.024	0.024	0.023	0.023	0.023	0.022	0.022	0.021
21.0	**0.020**	0.024	0.024	0.024	0.023	0.023	0.022	0.022	0.022	0.021	0.021	0.021	0.020	0.020
21.5	**0.019**	0.023	0.022	0.022	0.021	0.021	0.021	0.020	0.020	0.020	0.019	0.019	0.019	0.018
22.0	**0.018**	0.021	0.021	0.020	0.020	0.020	0.019	0.019	0.019	0.018	0.018	0.018	0.017	0.017
22.5	**0.016**	0.020	0.019	0.019	0.019	0.018	0.018	0.018	0.017	0.017	0.017	0.017	0.016	0.016
23.0	**0.015**	0.018	0.018	0.018	0.017	0.017	0.017	0.017	0.016	0.016	0.016	0.016	0.015	0.015
23.5	**0.014**	0.017	0.017	0.016	0.016	0.016	0.016	0.015	0.015	0.015	0.015	0.015	0.014	0.014
24.0	**0.014**	0.016	0.016	0.015	0.015	0.015	0.015	0.014	0.014	0.014	0.014	0.014	0.013	0.013

Table 12-2: Ct values, SO13-0S/SO13

12.2 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^3**	
Wind speed at hub height [m/s]		**Sound Power Level at Hub Height [dBA]** **Mode SO3 (Blades with serrated trailing edge, optional)**
3.0	91.9	
4.0	92.0	
5.0	92.0	
6.0	92.0	
7.0	92.8	
8.0	94.3	
9.0	95.7	
10.0	96.5	
11.0	96.8	
12.0	96.9	
13.0	97.0	
14.0	97.0	
15.0	97.0	

Table 12-3: Sound power level, SO13