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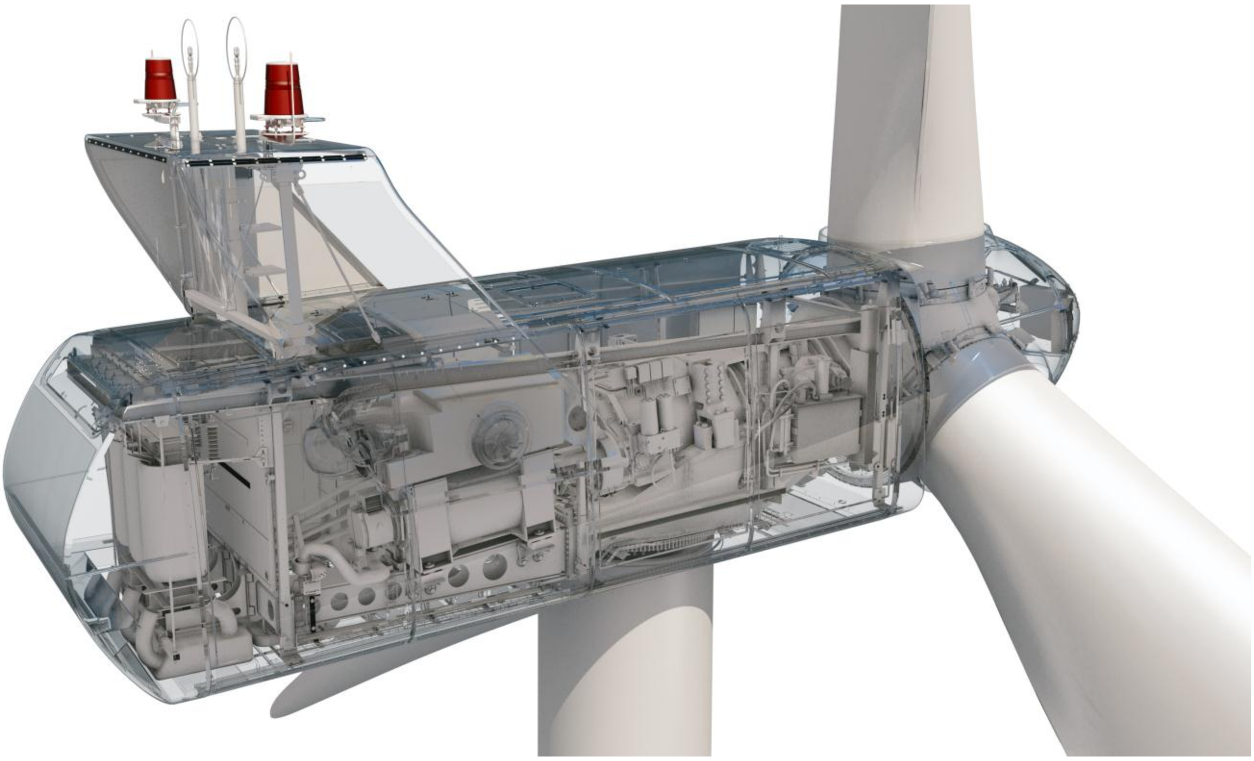
General Specification

V100-1.8/2.0 MW 50 Hz VCS



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See section 11 General Reservations, Notes and Disclaimers, p. 41 for general reservations, notes, and disclaimers applicable to these general specifications.

1 General Description

The Vestas V100-1.8/2.0 MW wind turbine is a pitch-regulated upwind turbine with active yaw and a three-blade rotor. The Vestas V100-1.8/2.0 MW turbine has a rotor diameter of 100 m with a generator rated at 1.8 MW. The turbine utilises a microprocessor pitch control system called OptiTip® and variable speed concepts (VCS: Vestas Converter System). With these features, the wind turbine is able to operate the rotor at variable speed revolutions per minute (rpm), helping to maintain the output at or near rated power.

2 Mechanical Design

2.1 Rotor

The V100-1.8/2.0 MW turbine is equipped with a 100-metre rotor consisting of three blades and the hub. Based on the prevailing wind conditions, the blades are continuously positioned to help optimise the pitch angle.

Rotor	
Diameter	100 m
Swept Area	7850 m^2
Rotational Speed Static, Rotor	14.9 rpm
Speed, Dynamic Operation Range	9.3–16.6 rpm
Rotational Direction	Clockwise (front view)
Orientation	Upwind
Tilt	6°
Hub Coning	2°
Number of Blades	3
Aerodynamic Brakes	Full feathering

Table 2-1: Rotor data.

2.2 Blades

The 49 m Prepreg (PP) blades are made of carbon and fibreglass. They consist of two airfoil shells bonded to a supporting beam.

PP Blades	
Type	Airfoil shells bonded to supporting beam
Blade Length	49 m
Material	Fibreglass reinforced epoxy and carbon fibres
Blade Connection	Steel roots inserted
Air Foils	RISØ P + FFA –W3
Chord	3.9 m
Blade Root Outer Diameter	1.88 m

PP Blades	
Pitch Circle Diameter of Steel Root Inserts	1.80 m
Blade Tip (R49)	0.54 m
Twist (Blade Root/Blade Tip)	245°/-0.5°
Approximate Weight	7500 kg

Table 2-2: PP blades data.

2.3 Blade Bearing

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

Blade Bearing	
Type	Double-row four-point contact ball bearing
Lubrication	Grease lubrication, automatic lubrication pump

Table 2-3: Blade bearing data.

2.4 Pitch System

The energy input from the wind to the turbine is adjusted by pitching the blades according to the control strategy. The pitch system also works as the primary brake system by pitching the blades out of the wind. This causes the rotor to idle.

Double-row four-point contact ball bearings are used to connect the blades to the hub. The pitch system relies on hydraulics and uses a cylinder to pitch each blade. Hydraulic power is supplied to the cylinder from the hydraulic power unit in the nacelle through the main gearbox and the main shaft via a rotating transfer.

Hydraulic accumulators inside the rotor hub ensure sufficient power to blades in case of failure.

Pitch System	
Type	Hydraulic
Cylinder	Ø 125/80–760
Number	1 piece/ blade
Range	-5° to 90°

Table 2-4: Pitch system data.

Hydraulic System	
Pump Capacity	50 l/minute
Working Pressure	200–230 bar
Oil Quantity	260 l
Motor	20 kW

Table 2-5: Hydraulic system data.

2.5 Hub

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

Hub	
Type	Cast ball shell hub
Material	Cast iron EN GJS 400-18U-LT / EN 1560

Table 2-6: Hub data.

2.6 Main Shaft

Main Shaft	
Type	Forged, trumpet shaft
Material	42 CrMo4 QT / EN 10083

Table 2-7: Main shaft data.

2.7 Bearing Housing

Bearing Housing	
Type	Cast foot housing with lowered centre
Material	Cast iron EN-GJS-400-18U-LT / EN 1560

Table 2-8: Bearing housing data.

2.8 Main Bearings

Main Bearings	
Type	Spherical roller bearings
Lubrication	Grease lubrication, manually re-greased

Table 2-9: Main bearings data.

2.9 Gearbox

The main gearbox transmits rotational torque from the rotor to the generator.

The main gearbox consists of a planetary stage combined with a two-stage parallel gearbox, torque arms and vibration dampers.

Torque is transmitted from the high-speed shaft to the generator via a flexible composite coupling located behind the disc brake. The disc brake is mounted directly on the high-speed shaft.

Gearbox	
Type	1 planetary stage + 2 helical stages
Ratio	1:113 nominal
Cooling	Oil pump with oil cooler
Oil Heater	2 kW
Maximum Gear Oil Temperature	80°C
Oil Cleanliness	-/15/12 ISO 4406

Table 2-10: Gearbox data.

2.10 Generator Bearings

The bearings are greased and grease is supplied continuously from an automatic lubrication unit when the nacelle temperature is above -10°C. The yearly grease flow is approximately 2400 cm³.

2.11 High-Speed Shaft Coupling

The flexible coupling transmits the torque from the gearbox high-speed output shaft to the generator input shaft. The flexible coupling is designed to compensate for misalignments between gearbox and generator. The coupling consists of two composite discs and an intermediate tube with two aluminium flanges and a fibreglass tube. The coupling is fitted to three-armed hubs on the brake disc and the generator hub.

High-Speed Shaft Coupling	
Type Description	VK 420

Table 2-11: High-speed shaft coupling data.

2.12 Yaw System

The yaw system is designed to keep the turbine upwind. The nacelle is mounted on the yaw plate that is bolted to the turbine tower. The yaw bearing system is a plain bearing system with built-in friction. Asynchronous yaw motors with brakes enable the nacelle to rotate on top of the tower.

The turbine controller receives wind direction information from the wind sensor. Automatic yawing is deactivated when the mean wind speed is below 3 m/s.

Yaw System	
Type	Plain bearing system with built-in friction
Material	Forged yaw ring heat-treated. Plain bearings PETP
Yawing Speed	< 0.5°/second

Table 2-12: Yaw system data.

Yaw Gear	
Type	Non-locking combined worm gear and planetary gearbox. Electrical motor brake
Motor	1.5 kW, 6 pole, asynchronous
Number of Yaw Gears	6
Ratio Total (Four Planetary Stages)	1,120 : 1
Rotational Speed at Full Load	Approximately 1 rpm at output shaft

Table 2-13: Yaw gear data.

2.13 Crane

The nacelle houses the service crane. The crane is a single system chain hoist.

Crane	
Lifting Capacity	Maximum 800 kg

Table 2-14: Crane data.

2.14 Tower Structure

Tubular towers with flange connections, certified according to relevant type approvals, are available in different standard heights. Magnets provide load support in a horizontal direction for tower internals, such as platforms, ladders, etc. Tower internals are supported vertically (i.e. in the gravitational direction) by mechanical connections.

The hub heights listed include a distance from the foundation section to the ground level of approximately 0.6 m depending on the thickness of the bottom flange and the distance from the tower top flange to the centre of the hub of 1.70 m.

Tower Structure	
Type	Conical tubular
Hub Heights	80 m / 95 m
Material	S355 according to EN 10024 A709 according to ASTM
Weight	80 m IEC S 160 metric tonnes* 95 m IEC S 205 metric tonnes**

Table 2-15: Tower structure data.

NOTE */** Typical values, dependent on wind class. Values can vary with site / project conditions.

2.15 Nacelle Bedplate and Cover

The nacelle cover is made of fibreglass. Hatches are positioned in the floor for lowering or hoisting equipment to the nacelle and evacuation of personnel.

The roof is equipped with wind sensors and skylights that can be opened from inside the nacelle to access the roof and from outside to access the nacelle. The nacelle cover is mounted on the girder structure. 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 nacelle bedplate carries the crane girders through vertical beams positioned along the site of the nacelle. 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 generator and the transformer.

Type Description	Material
Nacelle Cover	GRP
Bedplate Front	Cast EN-GJS-400-18U-LT / EN 1560
Bedplate Rear	Welded grid structure

Table 2-16: Nacelle bedplate and cover data.

2.16 Cooling

The cooling of the main components (gearbox, hydraulic power pack and VCS converter) in the turbine is done by a water cooling system. The generator is air cooled by nacelle air and the high-voltage (HV) transformer is cooled by mainly ambient air.

Component	Cooling Type	Internal Heating at Low Temperature
Nacelle	Forced air	Yes
Hub/Spinner	Natural air	No (yes for low-temperature (LT) turbines)
Gearbox	Water/oil	Yes
Generator	Forced air/air	No (heat source)
Slip rings	Forced air/air	Yes
Transformer	Forced air	No (heat source)
VCS	Forced water/air	Yes
VMP section	Forced air/air	Yes
Hydraulics	Water/oil	Yes

Table 2-17: Cooling summary.

All other heat generating systems are also equipped with fans and/or coolers but are considered minor contributors to nacelle thermodynamics.

2.17 Water Cooling System

The water cooling system is designed as a semi-closed system (closed system but not under pressure) with a free wind-water cooler on the roof of the nacelle. This means that the heat loss from the systems (components) is transferred to the water system, and the water system is cooled by ambient air.

The water cooling system has three parallel cooling circuits that cool the gearbox, the hydraulic power unit and the VCS converter.

The water cooling system is equipped with a three-way thermostatic valve. The valve is closed (total water flow bypasses the water cooler) if the temperature of the cooling water is below 35°C, and fully open (total water flow leads to the water cooler) if the temperature is above 43°C.

2.18 Gearbox Cooling

The gearbox cooling system consists of two oil circuits that remove the gearbox losses through two plate heat exchangers (oil coolers). The first circuit is equipped with a mechanically driven oil pump and a plate heat exchanger, and the second circuit is equipped with an electrically driven oil pump and a plate heat exchanger. The water circuit of the two plate heat exchangers is coupled in serial.

Gearbox Cooling	
Gear Oil Plate Heat Exchanger 1 (Mechanically driven oil pump)	
Nominal Oil Flow	50 l/minute
Oil Inlet Temperature	80°C
Number of Passes	2
Cooling Capacity	24.5 kW
Gear Oil Plate Heat Exchanger 2 (Electrically Driven Oil Pump)	
Nominal Oil Flow	85 l/minute
Oil Inlet Temperature	80°C
Number of Passes	2
Cooling Capacity	41.5 kW
Water Circuit	
Nominal Water Flow	Approximately 150 l/minute (50% glycol)
Water Inlet Temperature	Maximum 54°C
Number of Passes	1
Heat Load	66 kW

Table 2-18: Gearbox cooling data.

2.19 Hydraulic Cooling

The hydraulic cooling system consists of a plate heat exchanger that is mounted on the power pack. In the plate heat exchanger, the heat from the hydraulics is transferred to the water cooling system.

Hydraulic Cooling	
Hydraulic Oil Plate Heat Exchanger	
Nominal oil flow	40 l/minute
Oil inlet temperature	66°C
Cooling capacity	10.28 kW
Water Circuit	
Nominal water flow	Approximately 45 l/minute (50% glycol)
Water inlet temperature	Maximum 54°C
Heat load	10.28 kW

Table 2-19: Hydraulic cooling data.

2.20 VCS Converter Cooling

The converter cooling system consists of a number of switch modules that are mounted on cooling plates through which the cooling water is led.

Converter Cooling	
Nominal Water Flow	Approximately 45 l/minute (50% glycol)
Water Inlet Pressure	Maximum 2.0 bar
Water Inlet Temperature	Maximum 54°C
Cooling Capacity	10 kW

Table 2-20: Converter cooling data.

2.21 Generator Cooling

The generator cooling systems consists of an air-to-air cooler mounted on the top of the generator that removes the internal losses in the generator, two internal fans and one external fan. All the fans can run at low or high speed.

Generator Cooling	
Air Inlet Temperature: External	50°C
Nominal Air Flow: Internal	8000 m^3/h
Nominal Air Flow: External	7500 m^3/h
Cooling Capacity	48 kW

Table 2-21: Generator cooling data.

2.22 HV Transformer Cooling

The transformer is equipped with forced-air cooling. The cooling system consists of a central fan located under the service floor, an air distribution manifold, and six hoses leading to locations beneath and between the HV and LV windings.

Transformer Cooling	
Nominal Air Flow	1920 m^3/h
Air Inlet Temperature	Maximum 40°C

Table 2-22: Transformer cooling data.

2.23 Nacelle Conditioning

The nacelle conditioning system consists of one fan and two air heaters. There are two main circuits of the nacelle conditioning system that control the following:

1. Cooling of the HV transformer.
2. Heating and ventilation of the nacelle.

For both systems, the airflow enters the nacelle through louver dampers in the weather shield underneath the nacelle.

The cooling of the HV transformer is described in section 2.22 HV Transformer Cooling, p. 14.

The heating and ventilation of the nacelle is done by means of two air heaters and one fan. To avoid condensation in the nacelle, the two air heaters keep the nacelle temperature +5°C above the ambient temperature. At start-up in cold conditions, the heaters will also heat the air around the gearbox.

The ventilation of the nacelle is done by means of one fan that expels hot air generated by mechanical and electrical equipment from the nacelle.

Nacelle Cooling	
Nominal Air Flow	1.2 m^3/second
Air Inlet Temperature	Maximum 50°C

Table 2-23: Nacelle cooling data.

Nacelle Heating	
Rated Power	2 x 6 kW

Table 2-24: Nacelle heating data.

3 Electrical Design

3.1 Generator

The generator is a three-phase asynchronous generator with wound rotor that is connected to the Vestas Converter System (VCS) via a slip-ring system. The generator is an air-to-air cooled generator with internal and external cooling circuits. The external circuit uses air from the nacelle and expels it as exhaust out through the back of the nacelle.

The generator has four poles. The generator is wound with form windings in both rotor and stator. The stator is connected in star at low power and delta at high power. The rotor is connected in star and is insulated from the shaft. A slip ring is mounted to the rotor for the purpose of the VCS control.

Generator	
Type Description	Asynchronous with wound rotor, slip rings and VCS
Rated Power (PN)	1.8 MW-2.0 MW
Rated Apparent Power	2.0 MVA (Cosφ = 0.9)
Frequency	50 Hz
Voltage, Generator	690 Vac
Voltage, Converter	480 Vac
Number of Poles	4
Winding Type (Stator/Rotor)	Random/form
Winding Connection, Stator	Star/delta
Rated Efficiency (Generator Only)	> 97%
Power Factor (cos) 1.8 MW	0.90 ind–0.95 cap
Power Factor (cos) 2.0 MW	0.96 ind–0.98 cap
Overspeed Limit According to IEC (2 minute)	2900 rpm
Vibration Level	≤ 1.8 mm/s
Weight	Approximately 7500 kg
Generator Bearing – Temperature	Two PT100 sensors
Generator Stator Windings – Temperature	Three PT100 sensors placed at hot spots and three as backup

Table 3-1: Generator data.

3.2 HV Cables

The high-voltage cable runs from the transformer in the nacelle down the tower to the switchgear located in the bottom of the tower (switchgear is not included). The high-voltage cable is a four-core, rubber-insulated, halogen-free, high-voltage cable.

HV Cables	
High-Voltage Cable Insulation Compound	Improved ethylene-propylene (EP) based material – EPR or high modulus or hard grade ethylene-propylene rubber – HEPR
Conductor Cross Section	3 x 70/70 mm^2
Rated Voltage	12/20 kV (24 kV) or 20/35 kV (42 kV) depending on the transformer voltage

Table 3-2: HV cables data.

3.3 Transformer

The step-up transformer is located in a separate locked room in the back of the nacelle. The transformer is a three-phase, two-winding, dry-type transformer that is self- extinguishing. The windings are delta connected on the high-voltage side unless otherwise specified.

Transformer	
Type description	Dry-type cast resin transformer.
Basic layout	3 phase, 2 winding transformer with a tap on low voltage winding.
Applied standards	IEC 60076-11, IEC 60076-16, Cenelec HD 637:S1.
Cooling method	AF
Rated power HV / LV1 / LV2	2100 / 1900 / 200 kVA
Nominal voltage, turbine side LV1 / LV2	
U_m 1.1 kV	0.690 / 0.480 kV
Nominal voltage, grid side	
U_m 12.0 kV	6.0-11.0 kV
U_m 24.0 kV	11.1-22.0 kV
U_m 36.0 kV	22.1-33.0 kV
U_m 41.5 kV	33.1-35.0 kV
Insulation level AC / LI / LIC	
U_m 1.1 kV	3[1] / - / - kV
U_m 12.0 kV	28[1] / 75 / 75 kV
U_m 24.0 kV	50[1] / 125 / 125 kV
U_m 36.0 kV	70[1] / 170 / 170 kV
U_m 41.5 kV	80[1] / 170 / 170 kV
Off-circuit tap changer	±2 x 2.5 %

[1] @1000m. According to IEC 60076-11, AC test voltage is altitude dependent.

Transformer	
Frequency	50 Hz
Vector group	Dyn5 / YNyn0
No-load loss[2]	4.0 kW
Load loss @ rated power HV, 120°C [2]	19.0 kW
No-load reactive power[3]	16 kVAr
Full load reactive power [3]	220 kVAr
Positive sequence short-circuit impedance @ rated power LV1, 120°C[4]	
U_m 12.0-36.0 kV	7.8 %
U_m 41.5 kV	9.0 %
Positive sequence short-circuit resistance @ rated power LV1, 120°C[3]	
U_m 12.0-36.0 kV	0.8 %
U_m 41.5 kV	0.9 %
Zero sequence short-circuit impedance @ rated power LV1, 120°C[3]	
U_m 12.0-36.0 kV	7.3 %
U_m 41.5 kV	8.5 %
Zero sequence short-circuit resistance @ rated power LV1, 120°C[3]	
U_m 12.0-36.0 kV	0.8 %
U_m 41.5 kV	0.8 %
Inrush peak current [3]	
Dyn5	6-9 x $\hat{I}_n$
YNyn0	8-12 x $\hat{I}_n$
Half crest time [3]	~ 0.7 s
Sound power level	≤ 83 dB(A)
Average temperature rise @ 1000m	≤ 80 K
Max altitude[5]	2100 m
Insulation class	155 (F)
Environmental class	E2

[2] Based on an average of measured values during qualification tests across voltages and manufacturers.

[3] Based on an average of calculated values across voltages and manufacturers.

[4] Subject to standard IEC tolerances.

[5] Maximum hub height altitude will depend on site location.

Transformer	
Climatic class	C2
Fire behaviour class	F1
Corrosion class	C4
Weight	≤ 5500 kg
Temperature monitoring	PT100 sensors in LV windings
Overvoltage protection	Surge arresters on HV terminals
Temporary earthing	3 x Ø20mm earthing ball points

Table 3-3: Transformer data.

3.4 Converter

The converter controls the energy conversion in the generator. The VCS converter feeds power from the grid into the generator rotor at sub-sync speed and feeds power from the generator rotor to the grid at super-sync speed.

Converter	
Rated Slip	12%
Rated rpm	1680 rpm
Rated Rotor Power (@ rated slip)	193 kW
Rated Grid Current (@ rated slip, PF = 1 and 480 V)	232 A
Rated Rotor Current (@ rated slip and PF = 1)	573 A

Table 3-4: Converter data.

3.5 AUX System

The AUX System is supplied from the 690/480 V socket from the HV transformer. All motors, pumps, fans and heaters are supplied from this system.

All 230 V power sockets are supplied from a 690/230 V transformer.

Power Sockets	
Single Phase	230 V (13 A)
Three Phase	690 V (16 A)

Table 3-5: AUX system data.

3.6 Wind Sensors

The turbine is equipped with two ultrasonic wind sensors with built-in heaters.

Wind Sensors	
Type	FT702LT
Principle	Acoustic Resonance

Wind Sensors	
Built-In Heat	99 W

Table 3-6: Wind sensor data.

3.7 Turbine Controller

The turbine controller is based on the System 5000 controller hardware and Vestas VMP Global™ controller software.

The turbine controller is based on four main processors (ground, nacelle, hub and converter) which are interconnected by an optically based 2.5 Mbit ArcNet network.

I/O modules are connected either as rack modules in the System 3500 rack or by CAN.

The turbine control system serves the following main functions:

- Monitoring and supervision of overall operation.
- Synchronizing of the generator to the grid during connection sequence in order to limit the inrush current.
- Operating the wind turbine during various fault situations.
- Automatic yawing of the nacelle.
- OptiTip® – blade pitch control.
- Noise emission control.
- Monitoring of ambient conditions.
- Monitoring of the grid.

The turbine controller hardware is built from the following main modules:

Module	Function	Network
CT3603	Main processor. Control and monitoring (nacelle and hub).	ArcNet, CAN, Ethernet, serial
CT396	Main processor. Control, monitoring, external communication (ground).	ArcNet, CAN, Ethernet, serial
CT360	Main processor. Converter control and monitoring.	ArcNet, CAN, Ethernet
CT3218	Counter/encoder module. Azimuth, rpm and wind measurement.	Rack module
CT3133	24 Vdc digital input module. 16 channels.	Rack module
CT3153	24 Vdc digital output module. 16 channels.	Rack module
CT3320	Four-channel analogue input (0–10 V, 4–20 mA, PT100)	Rack module
CT6061	CAN I/O controller	CAN node
CT6221	Three-channel PT100 module	CAN I/O module
CT6050	Blade controller	CAN node
Balluf	Position transducer	CAN node

Module	Function	Network
Rexroth	Proportional valve	CAN node

Table 3-7: Turbine controller hardware.

3.8 Uninterruptible Power Supply (UPS)

The UPS supplies power to critical wind turbine components.

The actual backup time for the UPS system is proportional to the power consumption. Actual backup time may vary.

UPS		
Battery Type	Valve-Regulated Lead Acid (VRLA)	
Rated Battery Voltage	2 x 8 x 12 V (192 V)	
Converter Type	Double conversion online	
Rated Output Voltage	230 Vac	
Converter Input	230 V ±20%	
Backup Time*	Controller system	30 seconds
	Safety systems	35 minutes
Re-charging Time	Typical	Approximately 2.5 hours

Table 3-8: UPS data.

NOTE * For alternative backup times, consult Vestas.

4 Turbine Protection Systems

4.1 Braking Concept

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

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

4.2 Short-Circuit Protections

Breakers	**Generator / Q8 ABB E2B 2000 690 V**	**Controller / Q15 ABB S3X 690 V**	**VCS-VCUS / Q7 ABB S5H 400 480 V**
Breaking Capacity I_{cu}, I_{cs}	42, 42 kA	75, 75 kA	40, 40 kA
Making Capacity I_{cm} **(415 V Data)**	88 kA	440 kA	143 kA
Thermo Release I_{th}	2000 A	100 A	400 A

Table 4-1: Short-circuit protection data.

4.3 Overspeed Protection

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

The turbine is also equipped with a VOG (Vestas Overspeed Guard), an independent computer module measuring the rotor rpm. In case of an overspeed situation, the VOG activates the emergency feathered position (full feathering) of the three blades.

Overspeed Protection	
VOG Sensors Type	Inductive
Trip Levels	17.8 (rotor rpm) / 2013 (generator rpm)

Table 4-2: Overspeed protection data.

4.4 EMC System

The turbine and related equipment must fulfil the EU Electromagnetic Compatibility (EMC)-Directive with later amendments, including Council Directive 2004/108/EC of December 2004 on the approximation of the laws of the Member States relating to Electromagnetic Compatibility.

4.5 Lightning Protection System

The Lightning Protection System (LPS) consists of three main parts:

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

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

Table 4-3: Lightning design parameters.

NOTE The Lightning Protection System is designed according to IEC standards (see section 7.7 Design Codes – Lightning Protection, p. 28.

4.6 Earthing

The Vestas Earthing System is based on foundation earthing.

Vestas document no. 0000-3388 contains the list of documents regarding Vestas Earthing System.

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

4.7 Corrosion Protection

Classification of corrosion categories for atmospheric corrosion is according to ISO 9223:1992.

Corrosion Protection	External Areas	Internal Areas
Nacelle	C5	C3 and C4 Climate strategy: Heating the air inside the nacelle compared to the outside air temperature lowers the relative humidity and helps ensure a controlled corrosion level.
Hub	C5	C3
Tower	C5-I	C3

Table 4-4: Corrosion protection data for nacelle, hub and tower.

5 Safety

The safety specifications in this safety section provide limited general information about the safety features of the turbine and are not a substitute for Buyer and 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, (c) conducting all appropriate safety training and education and (d) reading and understanding all safety-related manuals and instructions. See section 5.13 Manuals and Warnings, p. 25 for additional guidance.

5.1 Access

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

5.2 Escape

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

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

Escape from the service lift is by ladder.

5.3 Rooms/Working Areas

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

5.4 Platforms, Standing and Working Places

The bottom tower section has three platforms. There is one platform at the entrance level (door level), one safety platform approximately three metres above the entrance platform and finally a platform in the top of the tower section.

Each middle tower section has one platform in the top of the tower section.

The top tower section has two platforms: a top platform and a service lift platform, where the service lift stops, below the top platform.

There are places to stand at various locations along the ladder.

The platforms have anti-slip surfaces.

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

5.5 Climbing Facilities

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

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

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

Over the crane hatch is an anchor point for the emergency descent equipment. The anchor point is tested to 22.2 kN.

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

5.6 Moving Parts, Guards and Blocking Devices

Moving parts in the nacelle are shielded.

The turbine is equipped with a rotor lock to prevent the rotor and drive train from rotating.

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

5.7 Lighting

All the turbine is equipped with lights in the tower, nacelle and in the hub.

There is emergency lighting in case of loss of electrical power.

5.8 Noise

When the turbine is out of operation for maintenance, the sound level in the nacelle is below 80 dB(A). Ear protection is required during operation mode.

5.9 Emergency Stop

There are emergency stops in the nacelle and in the bottom of the tower.

5.10 Power Disconnection

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

5.11 Fire Protection/First Aid

A 5 kg CO_2 fire extinguisher must be located in the nacelle at the left yaw gear. The location of the fire extinguisher, and how to use it, must be confirmed before operating the turbine.

A First Aid kit must be placed by the wall at the back end of the nacelle. The location of the First Aid kit, and how to use it, must be confirmed before operating the turbine.

There must be a fire blanket, above the generator, that can be used to put out small fires.

5.12 Warning Signs

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

5.13 Manuals and Warnings

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

6 Environment

6.1 Chemicals

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

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

7 Approvals, Certificates and Design Codes

7.1 Type Approvals

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

Certification	Wind Class	Hub Height
Type Certificate after IEC WT01 and IEC 61400-1:2005	IEC S*	80 m
	IEC S*	95 m

Table 7-1: Type approvals.

NOTE *Refer to section 9.1 Climate and Site Conditions, p. 29 for details.

7.2 Design Codes – Structural Design

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

Design Codes – Structural Design	
Nacelle and Hub	IEC 61400-1:2005 EN 50308 ANSI/ASSE Z359.1-2007
Bed Frame	IEC 61400-1:2005

Design Codes – Structural Design	
Tower	IEC 61400-1:2005 Eurocode 3 DIBt: Richtlinie für Windenergieanlagen, Einwirkungen und Standsicherheitsnachweise für Turm und Gründung, 4th edition.

Table 7-1: Structural design codes.

7.3 Design Codes – Mechanical Equipment

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

Design Codes – Mechanical Equipment	
Gear	Designed in accordance with rules in ISO 81400-4
Blades	DNV-OS-J102 IEC 1024-1 IEC 60721-2-4 IEC 61400 (Part 1, 12 and 23) IEC WT 01 IEC DEFU R25 ISO 2813 DS/EN ISO 12944-2

Table 7-2: Mechanical equipment design codes.

7.4 Design Codes – Electrical Equipment

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

Design Codes – Electrical Equipment	
High-Voltage AC Circuit Breakers	IEC 60056
High-Voltage Testing Techniques	IEC 60060
Power Capacitors	IEC 60831
Insulating Bushings for AC Voltage Above 1 kV	IEC 60137
Insulation Coordination	BS EN 60071
AC Disconnectors and Earth Switches	BS EN 60129
Current Transformers	IEC 60185
Voltage Transformers	IEC 60186
High-Voltage Switches	IEC 60265
Disconnectors and Fuses	IEC 60269
Flame Retardant Standard for MV Cables	IEC 60332
Transformer	IEC 60076-11

Design Codes – Electrical Equipment	
Generator	IEC 60034
Specification for Sulphur Hexafluoride for Electrical Equipment	IEC 60376
Rotating Electrical Machines	IEC 34
Dimensions and Output Ratings for Rotating Electrical Machines	IEC 72 and IEC 72A
Classification of Insulation, Materials for Electrical Machinery	IEC 85
Safety of Machinery – Electrical Equipment of Machines	IEC 60204-1

Table 7-3: Electrical equipment design codes.

7.5 Design Codes – I/O Network System

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

Design Codes – I/O Network System	
Salt Mist Test	IEC 60068-2-52
Damp Head, Cyclic	IEC 60068-2-30
Vibration Sinus	IEC 60068-2-6
Cold	IEC 60068-2-1
Enclosure	IEC 60529
Damp Head, Steady State	IEC 60068-2-56
Vibration Random	IEC 60068-2-64
Dry Heat	IEC 60068-2-2
Temperature Shock	IEC 60068-2-14
Free Fall	IEC 60068-2-32

Table 7-4: I/O Network system design codes.

7.6 Design Codes – EMC System

To fulfil EMC requirements the design must be as recommended for lightning protection. See section 7.7 Design Codes – Lightning Protection, p. 28.

Design Codes – EMC System	
Designed According to	IEC 61400-1: 2005
Further Robustness Requirements According to	TPS 901795

Table 7-5: EMC system design codes.

7.7 Design Codes – Lightning Protection

The LPS is designed according to Lightning Protection Level (LPL) I:

Design Codes – Lightning Protection	
Designed According to	IEC 62305-1: 2006 IEC 62305-3: 2006 IEC 62305-4: 2006
Non-Harmonized Standard and Technically Normative Documents	IEC/TR 61400-24:2002

Table 7-6: Lightning protection design codes.

7.8 Design Codes – Earthing

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

- IEC 62305-1 Ed. 1.0: Protection against lightning – Part 1: General principles.
- IEC 62305-3 Ed. 1.0: Protection against lightning – Part 3: Physical damage to structures and life hazard.
- IEC 62305-4 Ed. 1.0: Protection against lightning – Part 4: Electrical and electronic systems within structures.
- IEC/TR 61400-24. First edition. 2002-07. Wind turbine generator systems – Part 24: Lightning protection.
- IEC 60364-5-54. Second edition 2002-06. Electrical installations of buildings – Part 5-54: Selection and erection of electrical equipment – Earthing arrangements, protective conductors and protective bonding conductors.
- IEC 61936-1. First edition. 2002-10. Power installations exceeding 1 kV a.c. – Part 1: Common rules.

8 Colour and Surface Treatment

Gloss specifications are provided according to ISO 2813:2000 at a viewing angle of 60°. Exterior coatings are UV resistant.

8.1 Nacelle Colour and Surface Treatment

Surface Treatment of Vestas Nacelles	
Standard Nacelle Colours	RAL 7035 (light grey)
Gloss	80-95 gloss units
Standard Logo	Vestas

Table 8-1: Surface treatment, nacelle.

8.2 Tower Colour and Surface Treatment

Surface Treatment of Vestas Tower Section		
	External:	**Internal:**
Tower Colour Variants	RAL 7035 (light grey)	RAL 9001 (cream white)
Gloss	50-75 gloss units	Maximum 50 gloss units

Table 8-2: Surface treatment, tower.

8.3 Blades Colour

Blades Colour	
Blade Colour	RAL 7035 (light grey)
Tip-End Colour Variants	RAL 2009 (traffic orange), RAL 3000 (flame red), RAL 3020 (traffic red)
Gloss	≤ 20 gloss units

Table 8-3: Colours, blades.

9 Operational Envelope and Performance Guidelines

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

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

9.1 Climate and Site Conditions

Values refer to hub height:

Extreme Design Parameters	
Wind Climate	**IEC S**
Ambient Temperature Interval (Standard Temperature Turbine)	-30° to +50°C
Ambient Temperature Interval (Special Temperature Turbine)	+5° to +50°C
Ambient Temperature Interval (Low Temperature Turbine)	-40° to +50°C
Extreme Wind Speed (10 Minute Average)	42.5 m/s
Survival Wind Speed (3 Second Gust)	59.5 m/s

Table 9-1: Extreme design parameters.

NOTE The Ambient Temperature Interval (Special Temperature Turbine) +5° to +50°C is valid when the heaters are removed and is specific to V100-1.8/2.0 MW turbines in India.

Average Design Parameters – V100-1.8 MW	
Wind Climate	**IEC S**
Wind Speed	7.5 m/s
A-Factor	8.45 m/s
Form Factor, c	2
Turbulence Intensity According to IEC 61400-1, Including Wind Farm Turbulence (@15 m/s – 90% Quantile)	18%
Wind Shear	0.2
Inflow Angle (Vertical)	8°

Table 9-2: Average design parameters for V100-1.8 MW.

Average Design Parameters – V100-2.0 MW Power Mode	
Wind Climate	**IEC S**
Wind Speed	6.5 m/s
A-Factor	7.32 m/s
Form Factor, c	2
Turbulence Intensity According to IEC 61400-1, Including Wind Farm Turbulence (@15 m/s – 90% Quantile)	18%
Ambient Turbulence Intensity (@15 m/s – 90% Quantile)	16%
Wind Shear	0.2
Inflow Angle (Vertical)	8°

Table 9-3: Average design parameters for V100-2.0 MW.

9.1.1 Complex Terrain

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

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

9.1.2 Altitude

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

Above 1500 m, special considerations must be taken regarding, for example, HV installations and cooling performance. Consult Vestas for further information.

9.1.3 Wind Farm Layout

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

DISCLAIMER

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

9.2 Operational Envelope – Temperature and Wind

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

Operational Envelope – Temperature and Wind	
Ambient Temperature Interval (Standard Temperature Turbine)	-20° to +40°C
Ambient Temperature Interval (Special Temperature Turbine)	+5° to +40°C
Ambient Temperature Interval (Low Temperature Turbine)	-30° to +40°C
Cut-In (10 Minute Average)	3 m/s
Cut-Out (100 Second Exponential Average)	20 m/s
Re-Cut In (100 Second Exponential Average)	18 m/s

Table 9-3: Operational envelope - temperature and wind.

NOTE

The Ambient Temperature Interval (Special Temperature Turbine) +5° to +40°C is valid when the heaters are removed and is specific to V100-1.8/2.0 MW turbines in India.

9.3 Operational Envelope – Grid Connection*

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

Operational Envelope – Grid Connection		
Nominal Phase Voltage	$U_{P, nom}$	400 V
Nominal Frequency	f_{nom}	50 Hz
Maximum Steady State Voltage Jump	±2%	
Maximum Frequency Gradient	±4 Hz/second	
Maximum Negative Sequence Voltage	3%	

Table 9-4: Operational envelope – grid connection.

The generator and the converter will be disconnected if:

	U_P	U_N
Voltage is Above 110% of Nominal for 60 Seconds	440 V	759 V
Voltage is Above 115% of Nominal for 2 Seconds	460 V	794 V
Voltage is Above 120% of Nominal for 0.08 Seconds	480 V	828 V
Voltage is Above 125% of Nominal for 0.005 Seconds	500 V	863 V
Voltage is Below 90% of Nominal for 60 Seconds	360 V	621 V
Voltage is Below 85% of Nominal for 11 Seconds	340 V	586 V
Frequency is Above [Hz] for 0.2 Seconds	53 Hz	
Frequency is Below [Hz] for 0.2 Seconds	47 Hz	

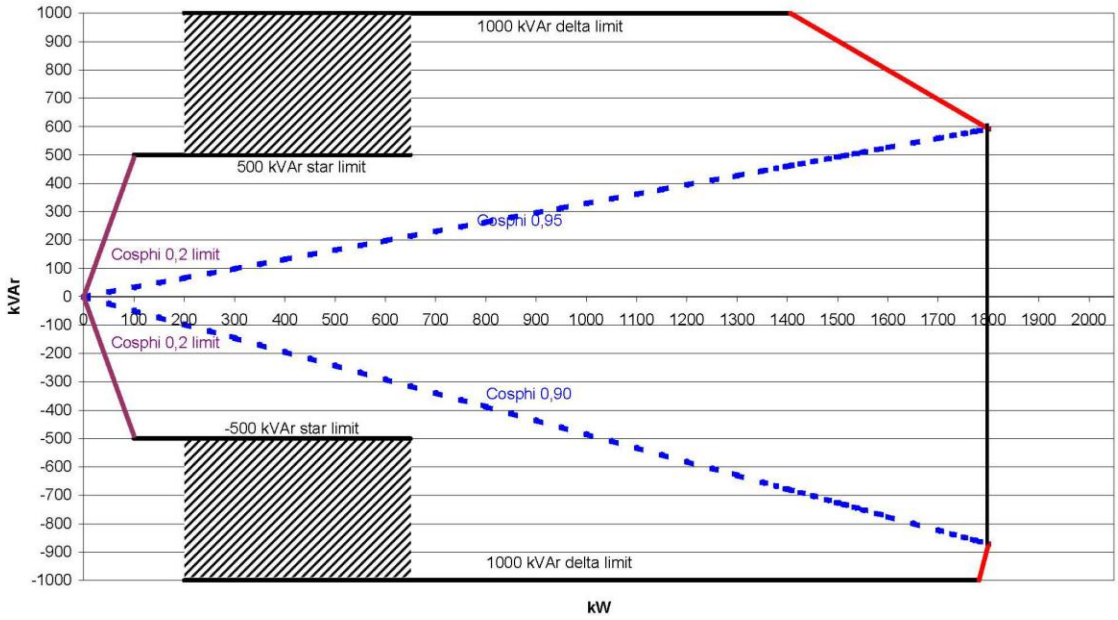
Table 9-5: Generator and converter disconnecting values.

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

9.4 Operational Envelope – Reactive Power Capability

The turbine has a reactive power capability dependent on power rating as illustrated in Figure 9-1, p. 33.

V100-1,8 MW reactive capability chart



V100-2.0 MW reactive capability chart

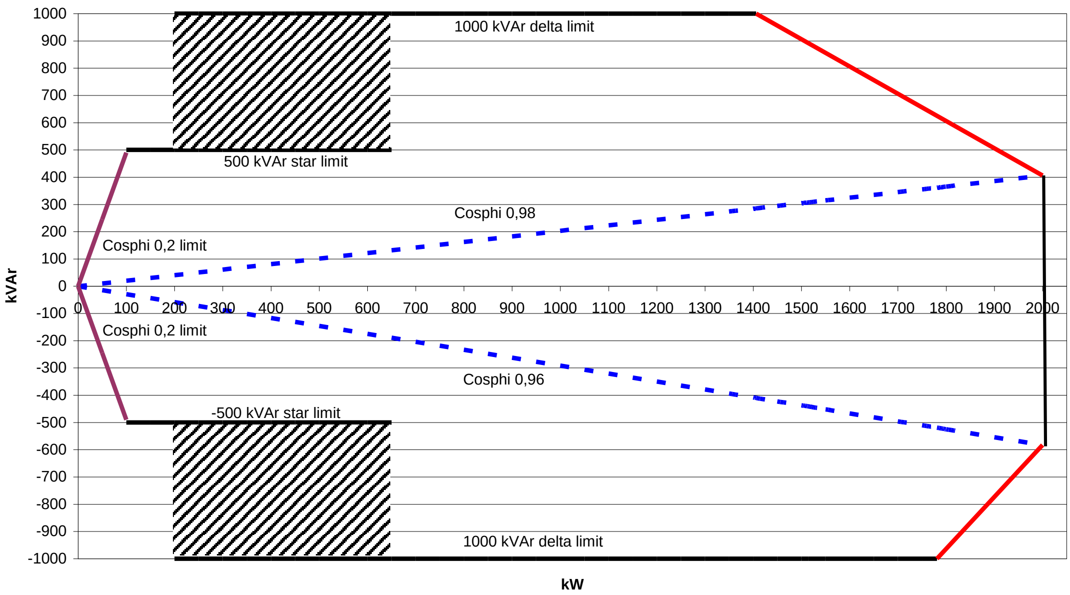


Figure 9-1: Reactive power capability.

The chart in Figure 9-1, p. 33 applies at the low-voltage side of the HV transformer. Reactive power is produced by the rotor converter and, therefore, traditional capacitors are not used in the turbine.

At maximum active and reactive power, the turbine reduces either active or reactive power depending on which type of power has priority (e.g. if reactive power has priority, the active power is reduced).

9.5 Performance – Fault Ride Through

The turbine is equipped with a reinforced Vestas Converter System to gain better control of the generator during grid faults. The controllers and contactors have a UPS backup system to keep the turbine control system running during grid faults.

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

The turbine is designed to stay connected during grid disturbances within the voltage tolerance curve in Figure 9-2, p. 34.

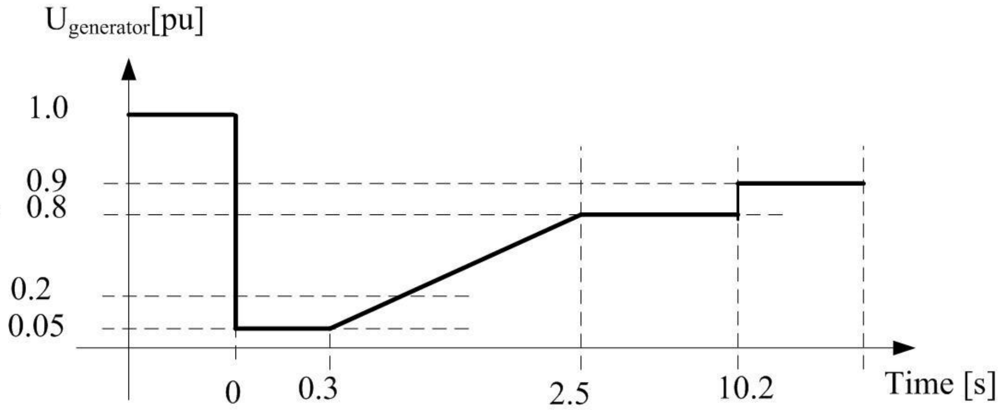


Figure 9-2: Low-voltage tolerance curve for symmetrical and asymmetrical faults.

For grid disturbances outside the protection curve in Figure 9-3, p. 34, the turbine will be disconnected from the grid.

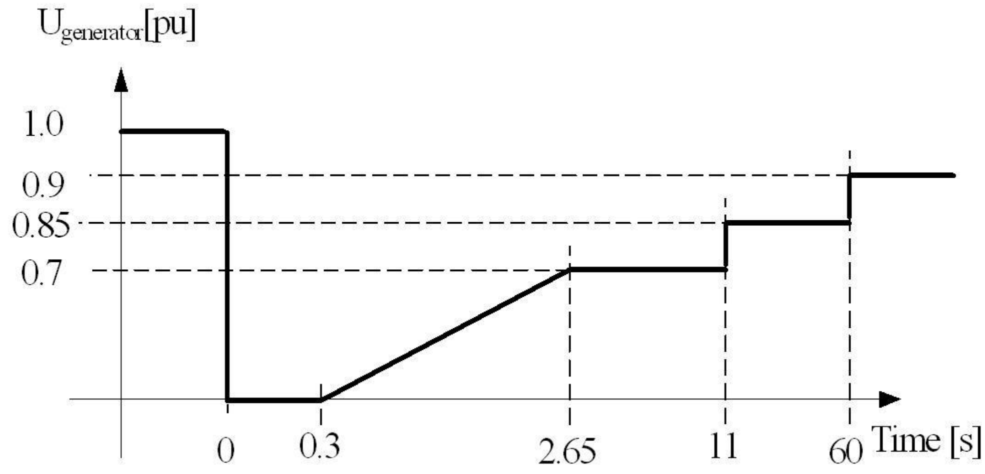


Figure 9-3: Default low-voltage protection settings for symmetrical and asymmetrical faults.

Power Recovery Time	
Power Recovery to 90% of Pre-Fault Level	Maximum 1.0 second

Table 9-6: Power recovery time.

9.6 Performance – Reactive Current Contribution

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

9.6.1 Symmetrical Reactive Current Contribution

During voltage dips the turbine is switched from normal active and reactive power control to rotor current control. This enables the turbine to perform voltage control by supplying reactive current to the grid. The reactive current at the generator terminals is set according to the voltage level at the generator terminals (see Figure 9-4, p. 35).

The default value gives a reactive current part of 1 pu of the rated turbine current at the generator terminals. Figure 9-4, p. 35 indicates the reactive current contribution as a function of the voltage at the generator terminals for star and delta operation. The reactive current contribution is independent from the actual wind conditions and pre-fault power level.

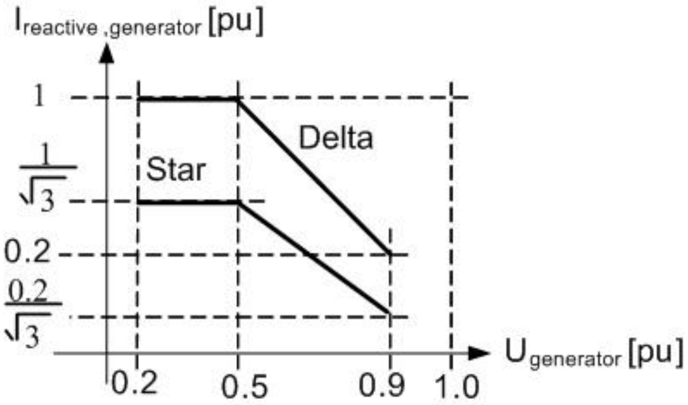


Figure 9-4: Reactive current contribution in star and delta drawn for 100% reactive current contribution.

In star connection, the reactive current contribution is lowered by a factor 1/√3 compared to the delta connection. Turbines may be operated in forced delta connection. This ensures full current injection by low wind.

During faults in the grid, high-voltage step (du/dt) in the grid voltage can occur that may pause the rotor current control for up to 50 ms before the rotor current control is resumed. During these 50 ms the generator can draw a low magnetisation current from the grid.

9.6.2 Asymmetrical Reactive Current Contribution

Current reference values are reduced during asymmetrical faults to ensure ride through. The current reference values are reduced from the symmetrical case with the following reduction factor on the current references:

$1-(u_{pu\_high} - u_{pu\_low})$

with ‘u_{pu_high}’ as the highest phase-to-phase or phase-to-ground RMS per unit voltage measured and ‘u_{pu_low}’ as the lowest phase-to-phase or phase-to-ground RMS per unit voltage.

9.7 Performance – Multiple Voltage Dips

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

9.8 Performance – Active and Reactive Power Control

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

Maximum Ramp Rates for External Control	
Active Power	0.1 pu/second
Reactive Power	2.5 pu/second

Table 9-7: Maximum ramp rates for external control.

To protect the turbine, active power cannot be controlled to values below the curve in Figure 9-5, p. 37.

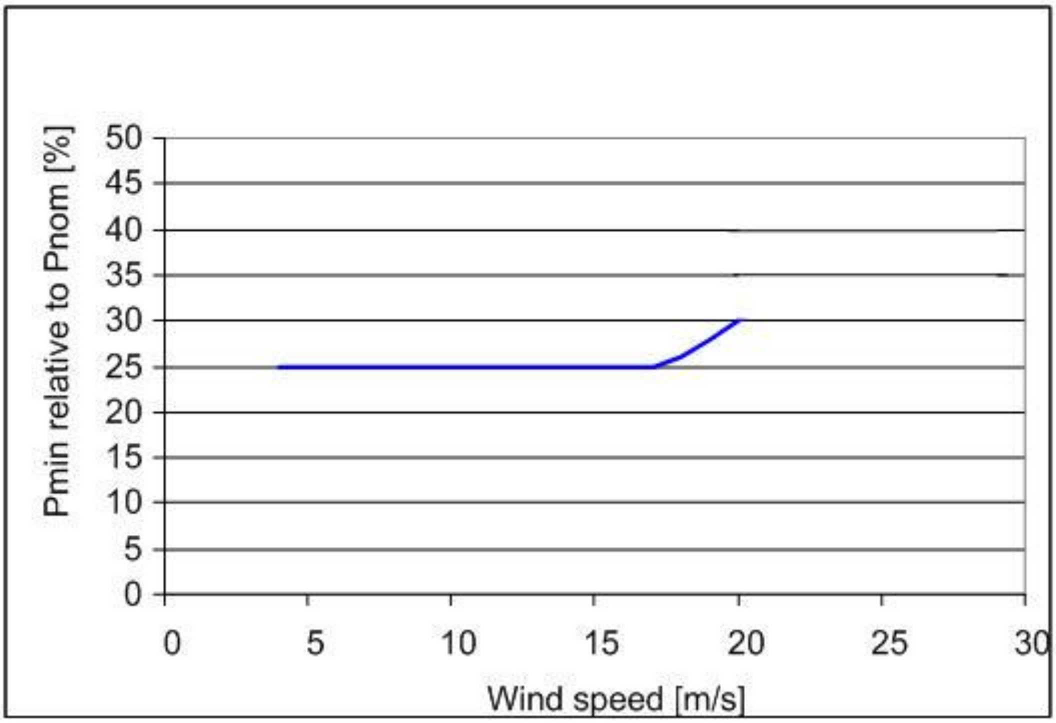


Figure 9-5: Minimum active power output dependent on wind speed.

9.9 Performance – Voltage Control

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

9.10 Performance – Frequency Control

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

Deadband and slope for the frequency control function are configurable.

9.11 Own Consumption

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

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

Own Consumption	
Hydraulic Motor	20 kW
Yaw Motors 6 x 1.75 kW	10.5 kW
Oil Heating 3 x 0.76 kW	2.3 kW
Air Heaters 2 x 6 kW (Standard) **3 x 6 kW (Low Temperature)**	12 kW (standard) 18 kW (low temperature)

Own Consumption	
Oil Pump for Gearbox Lubrication	3.5 kW
Average of measured no-load loss of the HV Transformer	4.0 kW

Table 9-8: Own consumption data.

9.12 Operational Envelope Conditions for Power Curve, C_t Values (at Hub Height)

See appendices in section 12 of this document for V100-1.8 MW through 2.0 MW power curves, C_t values and noise levels.

Conditions for Power Curve, C_t Values (at Hub Height)	
Wind Shear	0.00–0.30 (10 minute average)
Turbulence Intensity	6–12% (10 minute average)
Blades	Clean
Rain	No
Ice/Snow on Blades	No
Leading Edge	No damage
Terrain	IEC 61400-12-1
Inflow Angle (Vertical)	0 ± 2°
Grid Frequency	50 ± 0.5 Hz

Table 9-9: Conditions for power curve, C_t values.

10 Drawings

10.1 Structural Design – Illustration of Outer Dimensions

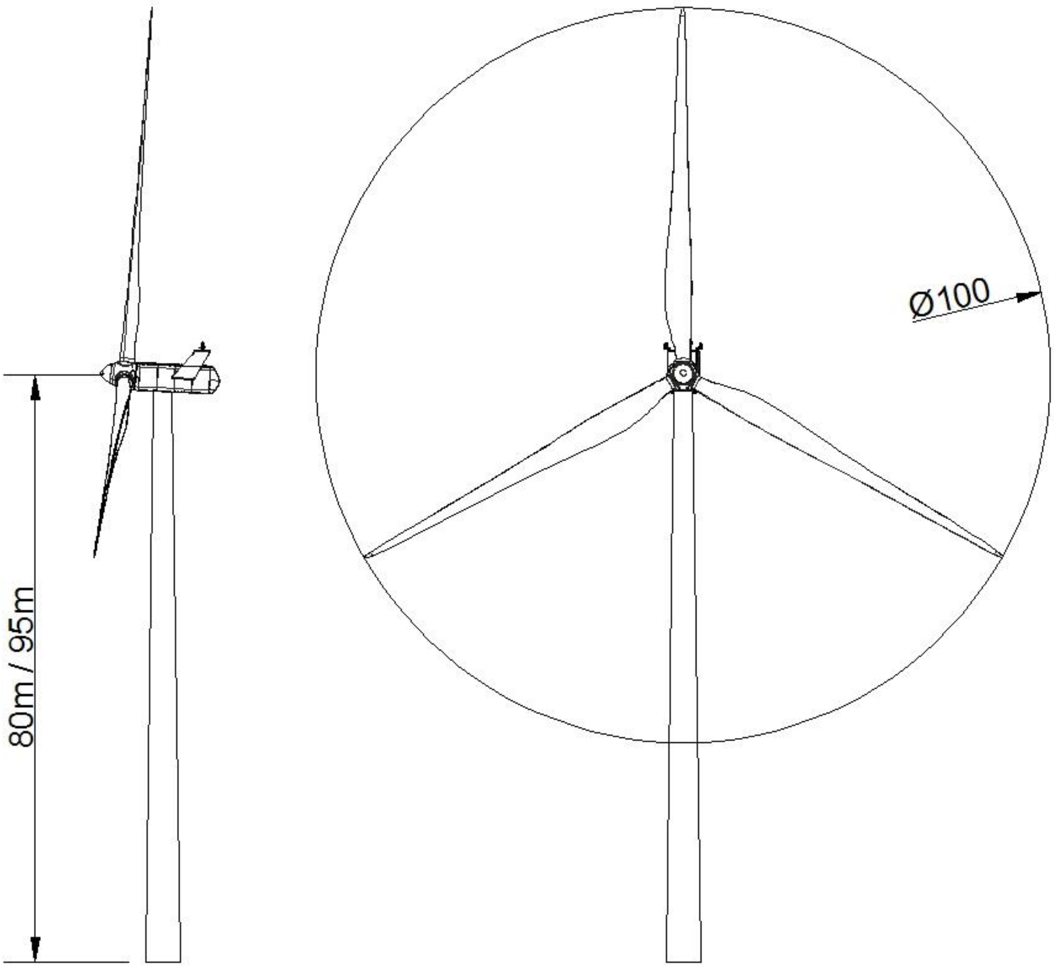


Figure 10-1: Illustration of outer dimensions: structure.

1 Hub height 60/67/78/80/100

2 Diameter: 80 m

10.2 Structural Design – Side-View Drawing

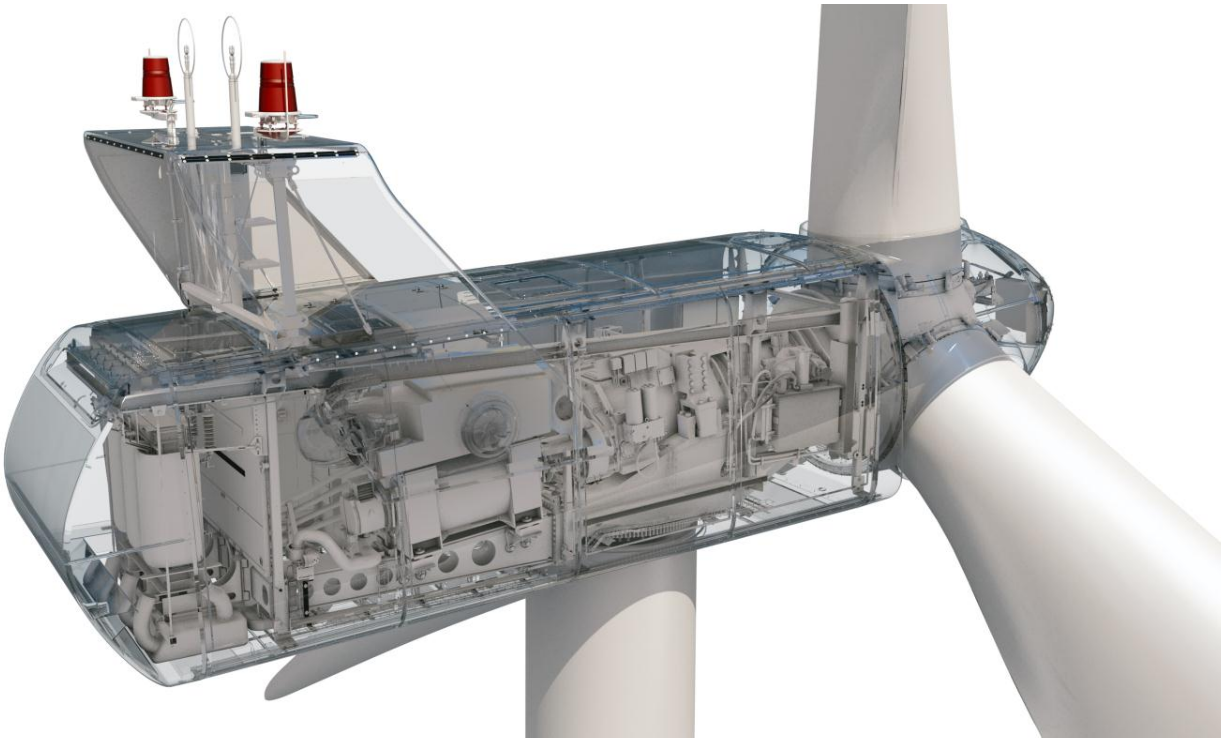


Figure 10-2: Side-view drawing.

11 General Reservations, Notes and Disclaimers

- The general specifications described in this document apply to the current version of the V100-1.8/2.0 MW wind turbine. Updated versions of the V100-1.8/2.0 MW wind turbine, which may be manufactured in the future, may have general specifications that differ from these general specifications. In the event that Vestas supplies an updated version of the V100-1.8/2.0 MW wind turbine, Vestas will provide updated general specifications applicable to the updated version.
- Vestas recommends that the grid be as close to nominal as possible with minimal variation in frequency.
- A certain time allowance for turbine warm-up must be expected following grid dropout and/or periods of very low ambient temperature.
- The estimated power curve for the different estimated noise levels (sound power levels) is for wind speeds at 10 minute average value at hub height and perpendicular to the rotor plane.
- All listed start/stop parameters (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 Specifications' is not, and does not contain, any guarantee, warranty and/or verification of the power curve and noise (including, without limitation, the power curve and noise verification method). Any guarantee, warranty and/or verification of the power curve and noise (including, without limitation, the power curve and noise verification method) must be agreed to separately in writing.

12 Appendices

Power curves, C_t values and sound power levels for noise mode 0 to 2 are defined below. These are values referencing 1.8 MW.

12.1 V100-1.8 MW Noise Mode 0

12.1.1 Power Curve, Noise Mode 0

V100-1.8 MW Power Curve, Noise Mode 0														
	Air density kg/m^3													
Wind speed [m/s]	**1.225**	**0.95**	**0.975**	**1.0**	**1.025**	**1.05**	**1.075**	**1.1**	**1.125**	**1.15**	**1.175**	**1.2**	**1.25**	**1.275**
3	**13**	9	9	10	10	10	11	11	12	12	12	13	14	14
3.5	**51**	34	35	37	39	40	42	43	45	46	48	50	53	54
4	**107**	78	80	83	86	89	91	94	97	99	102	105	110	113
4.5	**175**	131	135	139	143	147	151	155	159	163	167	171	179	183
5	**253**	193	198	204	209	215	220	226	231	237	242	248	259	264
5.5	**346**	265	272	279	287	294	302	309	316	324	331	338	353	360
6	**454**	349	359	368	378	387	397	406	416	425	435	444	463	473
6.5	**584**	447	459	472	484	497	509	522	534	547	559	571	596	609
7	**738**	567	583	598	614	630	645	661	676	692	707	723	754	769
7.5	**913**	704	723	742	761	780	799	818	837	856	875	894	931	950
8	**1107**	858	881	903	926	949	972	994	1017	1040	1062	1084	1129	1151
8.5	**1313**	1027	1053	1080	1106	1133	1159	1185	1211	1237	1262	1287	1338	1363
9	**1509**	1205	1235	1265	1294	1324	1352	1380	1407	1435	1460	1485	1531	1554
9.5	**1660**	1384	1414	1444	1475	1505	1530	1554	1579	1603	1622	1641	1676	1692
10	**1747**	1548	1572	1597	1622	1647	1664	1680	1697	1714	1725	1736	1755	1763
10.5	**1784**	1670	1686	1702	1719	1735	1744	1753	1762	1771	1775	1779	1786	1789
11	**1795**	1746	1754	1762	1770	1778	1781	1784	1787	1791	1792	1794	1796	1797
11.5	**1799**	1780	1783	1786	1789	1793	1794	1795	1796	1798	1798	1799	1800	1800
12	**1800**	1793	1794	1796	1797	1798	1799	1799	1799	1800	1800	1800	1800	1800
12.5	**1800**	1798	1799	1799	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800
13	**1800**	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800
13.5	**1800**	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800
14	**1800**	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800
14.5	**1800**	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800
15	**1800**	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800
15.5	**1800**	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800
16	**1800**	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800
16.5	**1800**	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800
17	**1800**	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800
17.5	**1800**	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800
18	**1800**	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800
18.5	**1800**	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800
19	**1800**	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800
19.5	**1800**	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800
20	**1800**	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800

Table 12-1: V100-1.8 MW Power Curve, Noise Mode 0.

12.1.2 V100-1.8 MW C_t Values, Noise Mode 0

V100-1.8 MW C_t Values, Noise Mode 0														
	Air density kg/m^3													
Wind speed [m/s]	**1.225**	**0.95**	**0.975**	**1.0**	**1.025**	**1.05**	**1.075**	**1.1**	**1.125**	**1.15**	**1.175**	**1.2**	**1.25**	**1.275**
3	**0.869**	0.871	0.871	0.870	0.870	0.870	0.870	0.870	0.870	0.870	0.870	0.870	0.869	0.869
3.5	**0.891**	0.891	0.891	0.891	0.891	0.891	0.891	0.891	0.891	0.891	0.891	0.891	0.891	0.891
4	**0.883**	0.882	0.882	0.882	0.882	0.883	0.883	0.883	0.883	0.883	0.883	0.883	0.883	0.883
4.5	**0.855**	0.855	0.855	0.855	0.855	0.855	0.855	0.855	0.855	0.855	0.855	0.855	0.855	0.855
5	**0.827**	0.826	0.826	0.826	0.826	0.826	0.826	0.826	0.826	0.826	0.826	0.826	0.826	0.826
5.5	**0.807**	0.807	0.807	0.807	0.807	0.807	0.807	0.807	0.807	0.807	0.807	0.807	0.807	0.808
6	**0.802**	0.801	0.801	0.801	0.801	0.801	0.801	0.802	0.802	0.802	0.802	0.802	0.802	0.802
6.5	**0.818**	0.817	0.817	0.817	0.817	0.817	0.817	0.817	0.817	0.817	0.817	0.817	0.818	0.818
7	**0.810**	0.809	0.809	0.809	0.809	0.809	0.809	0.809	0.810	0.810	0.810	0.810	0.810	0.810
7.5	**0.805**	0.805	0.805	0.805	0.805	0.805	0.805	0.805	0.805	0.805	0.805	0.805	0.804	0.804
8	**0.790**	0.800	0.799	0.798	0.798	0.797	0.796	0.795	0.795	0.794	0.793	0.791	0.789	0.788
8.5	**0.758**	0.781	0.779	0.777	0.775	0.773	0.771	0.769	0.767	0.765	0.763	0.760	0.755	0.753
9	**0.703**	0.747	0.744	0.740	0.737	0.734	0.730	0.726	0.722	0.718	0.713	0.708	0.697	0.691
9.5	**0.625**	0.699	0.693	0.688	0.683	0.678	0.671	0.664	0.657	0.650	0.642	0.633	0.616	0.607
10	**0.539**	0.644	0.635	0.626	0.618	0.609	0.599	0.590	0.580	0.570	0.559	0.549	0.528	0.518
10.5	**0.456**	0.577	0.566	0.555	0.544	0.533	0.522	0.511	0.499	0.488	0.477	0.467	0.446	0.436
11	**0.386**	0.507	0.494	0.482	0.470	0.457	0.447	0.436	0.425	0.414	0.405	0.395	0.378	0.369
11.5	**0.331**	0.437	0.426	0.414	0.403	0.392	0.382	0.373	0.364	0.354	0.347	0.339	0.324	0.317
12	**0.286**	0.377	0.368	0.358	0.348	0.338	0.330	0.322	0.314	0.306	0.300	0.293	0.281	0.275
12.5	**0.250**	0.328	0.320	0.311	0.303	0.294	0.288	0.281	0.274	0.267	0.262	0.256	0.245	0.240
13	**0.221**	0.288	0.280	0.273	0.266	0.259	0.253	0.247	0.241	0.235	0.230	0.226	0.216	0.212
13.5	**0.196**	0.254	0.248	0.242	0.235	0.229	0.224	0.219	0.214	0.209	0.205	0.200	0.192	0.189
14	**0.175**	0.226	0.221	0.215	0.210	0.204	0.200	0.195	0.191	0.187	0.183	0.179	0.172	0.169
14.5	**0.157**	0.202	0.197	0.193	0.188	0.183	0.179	0.175	0.171	0.167	0.164	0.161	0.155	0.152
15	**0.141**	0.181	0.177	0.173	0.168	0.164	0.161	0.157	0.154	0.150	0.147	0.144	0.139	0.136
15.5	**0.128**	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
16	**0.117**	0.149	0.145	0.142	0.138	0.135	0.132	0.129	0.127	0.124	0.121	0.119	0.115	0.112
16.5	**0.107**	0.135	0.132	0.129	0.126	0.123	0.121	0.118	0.116	0.113	0.111	0.109	0.105	0.103
17	**0.098**	0.124	0.121	0.118	0.115	0.113	0.110	0.108	0.106	0.104	0.102	0.100	0.096	0.094
17.5	**0.090**	0.114	0.111	0.109	0.106	0.104	0.101	0.099	0.097	0.095	0.094	0.092	0.088	0.087
18	**0.083**	0.105	0.102	0.100	0.098	0.095	0.093	0.092	0.090	0.088	0.086	0.085	0.082	0.080
18.5	**0.077**	0.097	0.094	0.092	0.090	0.088	0.086	0.085	0.083	0.081	0.080	0.078	0.075	0.074
19	**0.072**	0.090	0.088	0.086	0.084	0.082	0.081	0.079	0.077	0.076	0.074	0.073	0.070	0.069
19.5	**0.067**	0.083	0.082	0.080	0.078	0.076	0.075	0.073	0.072	0.070	0.069	0.068	0.066	0.064
20	**0.062**	0.078	0.076	0.074	0.073	0.071	0.070	0.068	0.067	0.066	0.064	0.063	0.061	0.060

Table 12-2: V100-1.8 MW C_t values, Noise Mode 0.

12.1.3 V100-1.8 MW Sound Power Levels, Noise Mode 0

V100-1.8 MW Sound Power Level at Hub Height, Noise Mode 0		
Conditions for Sound Power Level:	**Measurement standard IEC 61400-11 Ed. 2.** **Wind shear: 0.15** **Maximum turbulence at 10 metre height: 16%** **Inflow angle (vertical): 0 ± 2°** **Air density: 1.225 kg/m^3**	
Hub Height	**80 m**	**95 m**
LwA @ 3 m/s (10 m above ground) [dBA] Wind speed at hub height [m/s]	94.0 4.2	94.1 4.3
LwA @ 4 m/s (10 m above ground) [dBA] Wind speed at hub height [m/s]	95.9 5.6	96.4 5.7
LwA @ 5 m/s (10 m above ground) [dBA] Wind speed at hub height [m/s]	100.1 7.0	100.6 7.2
LwA @ 6 m/s (10 m above ground) [dBA] Wind speed at hub height [m/s]	103.8 8.4	104.3 8.6
LwA @ 7 m/s (10 m above ground) [dBA] Wind speed at hub height [m/s]	105.0 9.8	105.0 10.0
LwA @ 8 m/s (10 m above ground) [dBA] Wind speed at hub height [m/s]	105.0 11.2	105.0 11.5
LwA @ 9 m/s (10 m above ground) [dBA] Wind speed at hub height [m/s]	105.0 12.6	105.0 12.9
LwA @ 10 m/s (10 m above ground) [dBA] Wind speed at hub height [m/s]	105.0 13.9	105.0 14.3
LwA @ 11 m/s (10 m above ground) [dBA] Wind speed at hub height [m/s]	105.0 15.3	105.0 15.8
LwA @ 12 m/s (10 m above ground) [dBA] Wind speed at hub height [m/s]	105.0 16.7	105.0 17.2
LwA @ 13 m/s (10 m above ground) [dBA] Wind speed at hub height [m/s]	105.0 18.1	105.0 18.6

Table 12-3: V100-1.8 MW sound power level at hub height, Noise Mode 0.

12.2 V100-1.8 MW Noise Mode 1

12.2.1 Power Curve, Noise Mode 1

V100-1.8 MW Power Curve, Noise Mode 1														
	Air density kg/m³													
Wind speed [m/s]	**1.225**	**0.95**	**0.975**	**1.0**	**1.025**	**1.05**	**1.075**	**1.1**	**1.125**	**1.15**	**1.175**	**1.2**	**1.25**	**1.275**
3	**13**	9	9	9	10	10	11	11	11	12	12	13	14	14
3.5	**51**	34	35	37	39	40	42	43	45	46	48	50	53	54
4	**107**	77	80	83	85	88	91	94	96	99	102	104	110	112
4.5	**172**	129	133	137	141	145	149	153	157	161	165	168	176	180
5	**247**	187	193	198	204	209	214	220	225	231	236	241	252	257
5.5	**335**	256	263	270	278	285	292	299	306	313	321	328	342	349
6	**439**	338	347	356	366	375	384	393	403	412	421	430	448	458
6.5	**575**	440	452	465	477	489	502	514	526	538	551	563	588	600
7	**727**	558	573	589	604	620	635	650	666	681	696	711	742	757
7.5	**899**	693	712	730	749	768	787	805	824	843	862	880	918	936
8	**1094**	846	869	891	914	937	959	982	1004	1027	1049	1072	1116	1138
8.5	**1304**	1016	1043	1069	1096	1122	1149	1175	1201	1227	1253	1278	1329	1354
9	**1506**	1198	1227	1257	1287	1317	1346	1374	1402	1431	1456	1481	1529	1551
9.5	**1661**	1380	1410	1441	1472	1503	1528	1553	1578	1603	1622	1642	1676	1692
10	**1747**	1546	1571	1596	1621	1646	1663	1680	1697	1714	1725	1736	1754	1762
10.5	**1783**	1669	1686	1702	1719	1735	1744	1753	1761	1770	1774	1779	1785	1787
11	**1796**	1747	1755	1763	1770	1778	1782	1785	1788	1791	1793	1794	1796	1797
11.5	**1799**	1780	1783	1787	1790	1793	1794	1795	1796	1798	1798	1799	1799	1800
12	**1800**	1793	1794	1795	1797	1798	1799	1799	1799	1800	1800	1800	1800	1800
12.5	**1800**	1798	1799	1799	1799	1800	1800	1800	1800	1800	1800	1800	1800	1800
13	**1800**	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800
13.5	**1800**	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800
14	**1800**	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800
14.5	**1800**	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800
15	**1800**	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800
15.5	**1800**	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800
16	**1800**	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800
16.5	**1800**	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800
17	**1800**	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800
17.5	**1800**	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800
18	**1800**	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800
18.5	**1800**	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800
19	**1800**	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800
19.5	**1800**	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800
20	**1800**	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800

Table 12-4: V100-1.8 MW Power Curve, Noise Mode 1.

12.2.2 V100-1.8 MW C_t Values, Noise Mode 1

V100-1.8 MW C_t Values, Noise Mode 1														
	Air density kg/m^3													
Wind speed [m/s]	**1.225**	**0.95**	**0.975**	**1.0**	**1.025**	**1.05**	**1.075**	**1.1**	**1.125**	**1.15**	**1.175**	**1.2**	**1.25**	**1.275**
3	**0.862**	0.863	0.863	0.863	0.863	0.863	0.863	0.862	0.862	0.862	0.862	0.862	0.862	0.862
3.5	**0.866**	0.866	0.866	0.866	0.866	0.866	0.866	0.866	0.866	0.866	0.866	0.866	0.866	0.866
4	**0.838**	0.838	0.838	0.838	0.838	0.838	0.838	0.838	0.838	0.838	0.838	0.838	0.839	0.839
4.5	**0.788**	0.787	0.787	0.788	0.788	0.788	0.788	0.788	0.788	0.788	0.788	0.788	0.788	0.788
5	**0.744**	0.744	0.744	0.744	0.744	0.744	0.744	0.744	0.744	0.744	0.744	0.744	0.744	0.744
5.5	**0.717**	0.717	0.717	0.717	0.717	0.717	0.717	0.717	0.717	0.718	0.718	0.717	0.718	0.718
6	**0.710**	0.709	0.709	0.709	0.709	0.709	0.709	0.709	0.710	0.709	0.710	0.710	0.710	0.710
6.5	**0.753**	0.752	0.752	0.752	0.752	0.753	0.753	0.753	0.753	0.753	0.753	0.753	0.753	0.753
7	**0.744**	0.743	0.743	0.743	0.743	0.743	0.744	0.744	0.744	0.744	0.744	0.744	0.744	0.744
7.5	**0.740**	0.739	0.739	0.740	0.740	0.740	0.740	0.740	0.740	0.740	0.740	0.740	0.740	0.740
8	**0.738**	0.740	0.740	0.740	0.740	0.740	0.739	0.739	0.739	0.739	0.739	0.738	0.738	0.737
8.5	**0.724**	0.736	0.735	0.734	0.734	0.733	0.731	0.730	0.729	0.728	0.727	0.725	0.723	0.721
9	**0.688**	0.720	0.717	0.715	0.713	0.711	0.708	0.706	0.703	0.700	0.696	0.692	0.682	0.677
9.5	**0.620**	0.687	0.683	0.679	0.674	0.670	0.664	0.657	0.651	0.644	0.636	0.628	0.611	0.602
10	**0.536**	0.639	0.631	0.623	0.615	0.607	0.597	0.587	0.577	0.567	0.557	0.546	0.525	0.515
10.5	**0.454**	0.576	0.565	0.554	0.543	0.532	0.521	0.509	0.498	0.487	0.476	0.465	0.444	0.434
11	**0.386**	0.507	0.494	0.482	0.470	0.457	0.446	0.436	0.425	0.414	0.404	0.395	0.377	0.369
11.5	**0.331**	0.437	0.426	0.414	0.403	0.392	0.382	0.373	0.364	0.354	0.346	0.339	0.324	0.317
12	**0.286**	0.377	0.368	0.358	0.348	0.338	0.330	0.322	0.314	0.306	0.300	0.293	0.280	0.275
12.5	**0.250**	0.328	0.320	0.311	0.303	0.294	0.288	0.281	0.274	0.267	0.262	0.256	0.245	0.240
13	**0.221**	0.288	0.280	0.273	0.266	0.259	0.253	0.247	0.241	0.235	0.230	0.226	0.216	0.212
13.5	**0.196**	0.254	0.248	0.242	0.235	0.229	0.224	0.219	0.214	0.209	0.205	0.200	0.192	0.189
14	**0.175**	0.226	0.221	0.215	0.210	0.204	0.200	0.195	0.191	0.187	0.183	0.179	0.172	0.169
14.5	**0.157**	0.202	0.197	0.193	0.188	0.183	0.179	0.175	0.171	0.167	0.164	0.161	0.155	0.152
15	**0.141**	0.181	0.177	0.173	0.168	0.164	0.161	0.157	0.154	0.150	0.147	0.144	0.139	0.136
15.5	**0.128**	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
16	**0.117**	0.149	0.145	0.142	0.138	0.135	0.132	0.129	0.127	0.124	0.121	0.119	0.115	0.112
16.5	**0.107**	0.135	0.132	0.129	0.126	0.123	0.121	0.118	0.116	0.113	0.111	0.109	0.105	0.103
17	**0.098**	0.124	0.121	0.118	0.115	0.113	0.110	0.108	0.106	0.104	0.102	0.100	0.096	0.094
17.5	**0.090**	0.114	0.111	0.109	0.106	0.104	0.101	0.099	0.097	0.095	0.094	0.092	0.088	0.087
18	**0.083**	0.105	0.102	0.100	0.098	0.095	0.093	0.092	0.090	0.088	0.086	0.085	0.082	0.080
18.5	**0.077**	0.097	0.094	0.092	0.090	0.088	0.086	0.085	0.083	0.081	0.080	0.078	0.075	0.074
19	**0.072**	0.090	0.088	0.086	0.084	0.082	0.081	0.079	0.077	0.076	0.074	0.073	0.070	0.069
19.5	**0.067**	0.083	0.082	0.080	0.078	0.076	0.075	0.073	0.072	0.070	0.069	0.068	0.066	0.064
20	**0.062**	0.078	0.076	0.074	0.073	0.071	0.070	0.068	0.067	0.066	0.064	0.063	0.061	0.060

Table 12-5: V100-1.8 MW C_t values, Noise Mode 1.

12.2.3 V100-1.8 MW Sound Power Levels, Noise Mode 1

V100-1.8 MW Sound Power Level at Hub Height, Mode 1		
Conditions for Sound Power Level:	**Measurement standard IEC 61400-11 Ed. 2.** **Wind shear: 0.15** **Maximum turbulence at 10 metre height: 16%** **Inflow angle (vertical): 0 ± 2°** **Air density: 1.225 kg/m^3**	
Hub Height	**80 m**	**95 m**
LwA @ 3 m/s (10 m above ground) [dBA] Wind speed at hub height [m/s]	93.9 4.2	93.9 4.3
LwA @ 4 m/s (10 m above ground) [dBA] Wind speed at hub height [m/s]	95.4 5.6	95.7 5.7
LwA @ 5 m/s (10 m above ground) [dBA] Wind speed at hub height [m/s]	99.0 7.0	99.6 7.2
LwA @ 6 m/s (10 m above ground) [dBA] Wind speed at hub height [m/s]	102.8 8.4	103.3 8.6
LwA @ 7 m/s (10 m above ground) [dBA] Wind speed at hub height [m/s]	105.0 9.8	105.0 10.0
LwA @ 8 m/s (10 m above ground) [dBA] Wind speed at hub height [m/s]	105.0 11.2	105.0 11.5
LwA @ 9 m/s (10 m above ground) [dBA] Wind speed at hub height [m/s]	105.0 12.6	105.0 12.9
LwA @ 10 m/s (10 m above ground) [dBA] Wind speed at hub height [m/s]	105.0 13.9	105.0 14.3
LwA @ 11 m/s (10 m above ground) [dBA] Wind speed at hub height [m/s]	105.0 15.3	105.0 15.8
LwA @ 12 m/s (10 m above ground) [dBA] Wind speed at hub height [m/s]	105.0 16.7	105.0 17.2
LwA @ 13 m/s (10 m above ground) [dBA] Wind speed at hub height [m/s]	105.0 18.1	105.0 18.6

Table 12-6: V100-1.8 MW Sound power level at hub height, Noise Mode 1.

12.3 V100-1.8 MW Noise Mode 2

12.3.1 Power Curve, Noise Mode 2

V100-1.8 MW Power Curve, Noise Mode 2														
	Air density kg/m^3													
Wind speed [m/s]	**1.225**	**0.95**	**0.975**	**1.0**	**1.025**	**1.05**	**1.075**	**1.1**	**1.125**	**1.15**	**1.175**	**1.2**	**1.25**	**1.275**
3	**13**	9	9	10	10	10	11	11	12	12	12	13	14	14
3.5	**51**	34	35	37	39	40	42	43	45	46	48	50	53	54
4	**107**	78	80	83	86	89	91	94	97	99	102	105	110	113
4.5	**175**	131	135	139	143	147	151	155	159	163	167	171	179	183
5	**253**	193	198	204	209	215	220	226	231	237	242	248	259	264
5.5	**345**	264	272	279	286	294	301	309	316	323	331	338	353	360
6	**453**	349	358	368	377	387	397	406	416	425	434	444	463	472
6.5	**584**	446	459	472	484	497	509	522	534	546	559	571	596	609
7	**738**	567	582	598	613	629	645	660	676	691	707	722	753	768
7.5	**909**	701	720	739	758	777	796	815	834	853	872	890	928	947
8	**1092**	843	866	888	911	934	956	979	1001	1024	1047	1069	1114	1136
8.5	**1271**	983	1010	1036	1062	1089	1115	1141	1167	1193	1219	1245	1297	1323
9	**1431**	1110	1139	1169	1199	1228	1257	1287	1316	1345	1374	1402	1458	1486
9.5	**1552**	1212	1244	1276	1308	1340	1371	1402	1433	1465	1494	1523	1578	1603
10	**1633**	1289	1323	1357	1390	1424	1456	1488	1520	1552	1579	1606	1655	1678
10.5	**1689**	1350	1385	1420	1455	1490	1521	1552	1583	1614	1639	1664	1707	1726
11	**1734**	1415	1450	1485	1521	1556	1585	1615	1644	1673	1694	1714	1747	1759
11.5	**1764**	1488	1522	1556	1590	1624	1649	1674	1698	1723	1737	1750	1772	1780
12	**1783**	1575	1605	1634	1664	1693	1710	1727	1743	1760	1768	1775	1787	1791
12.5	**1792**	1661	1681	1702	1723	1743	1753	1762	1772	1781	1785	1788	1794	1795
13	**1797**	1724	1737	1749	1761	1773	1778	1782	1787	1791	1793	1795	1797	1798
13.5	**1800**	1757	1765	1772	1780	1788	1790	1793	1795	1798	1798	1799	1800	1800
14	**1800**	1784	1787	1791	1794	1798	1798	1799	1799	1800	1800	1800	1800	1800
14.5	**1800**	1797	1797	1798	1799	1800	1800	1800	1800	1800	1800	1800	1800	1800
15	**1800**	1797	1798	1798	1799	1799	1799	1800	1800	1800	1800	1800	1800	1800
15.5	**1800**	1799	1799	1799	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800
16	**1800**	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800
16.5	**1800**	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800
17	**1800**	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800
17.5	**1800**	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800
18	**1800**	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800
18.5	**1800**	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800
19	**1800**	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800
19.5	**1800**	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800
20	**1800**	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800	1800

Table 12-7: V100-1.8 MW Power Curve, Noise Mode 2.

12.3.2 V100-1.8 MW C_t Values, Noise Mode 2

V100-1.8 MW C_t Values, Noise Mode 2														
	Air density kg/m^3													
Wind speed [m/s]	**1.225**	**0.95**	**0.975**	**1.0**	**1.025**	**1.05**	**1.075**	**1.1**	**1.125**	**1.15**	**1.175**	**1.2**	**1.25**	**1.275**
3	**0.868**	0.869	0.869	0.869	0.869	0.869	0.869	0.868	0.868	0.868	0.868	0.868	0.868	0.868
3.5	**0.888**	0.888	0.888	0.888	0.888	0.888	0.888	0.888	0.888	0.888	0.888	0.888	0.888	0.888
4	**0.882**	0.881	0.881	0.881	0.881	0.881	0.881	0.881	0.881	0.881	0.881	0.882	0.882	0.882
4.5	**0.854**	0.853	0.853	0.854	0.854	0.854	0.854	0.854	0.854	0.854	0.854	0.854	0.854	0.854
5	**0.823**	0.822	0.822	0.822	0.822	0.822	0.822	0.822	0.822	0.822	0.822	0.822	0.822	0.822
5.5	**0.801**	0.801	0.801	0.801	0.801	0.801	0.801	0.801	0.801	0.801	0.801	0.801	0.801	0.801
6	**0.796**	0.794	0.794	0.795	0.795	0.795	0.795	0.795	0.795	0.795	0.795	0.796	0.796	0.795
6.5	**0.815**	0.814	0.814	0.814	0.814	0.814	0.814	0.814	0.815	0.815	0.815	0.815	0.815	0.815
7	**0.803**	0.802	0.802	0.802	0.802	0.802	0.803	0.803	0.803	0.803	0.803	0.803	0.803	0.803
7.5	**0.784**	0.784	0.784	0.784	0.784	0.784	0.784	0.784	0.784	0.784	0.784	0.784	0.784	0.785
8	**0.748**	0.748	0.748	0.748	0.748	0.748	0.748	0.748	0.748	0.748	0.748	0.748	0.748	0.748
8.5	**0.696**	0.695	0.695	0.695	0.695	0.695	0.695	0.696	0.696	0.696	0.696	0.696	0.696	0.696
9	**0.631**	0.632	0.632	0.632	0.632	0.632	0.632	0.632	0.632	0.632	0.632	0.632	0.631	0.630
9.5	**0.558**	0.562	0.562	0.562	0.563	0.563	0.562	0.562	0.562	0.561	0.560	0.559	0.556	0.554
10	**0.486**	0.496	0.496	0.496	0.496	0.496	0.496	0.495	0.494	0.493	0.491	0.489	0.483	0.479
10.5	**0.422**	0.437	0.437	0.436	0.436	0.436	0.435	0.433	0.432	0.430	0.428	0.425	0.417	0.413
11	**0.367**	0.388	0.387	0.387	0.386	0.386	0.384	0.382	0.380	0.378	0.374	0.371	0.362	0.357
11.5	**0.321**	0.350	0.349	0.348	0.347	0.346	0.343	0.340	0.337	0.334	0.330	0.326	0.316	0.311
12	**0.282**	0.321	0.319	0.317	0.315	0.313	0.309	0.305	0.301	0.297	0.292	0.287	0.277	0.272
12.5	**0.248**	0.297	0.293	0.289	0.286	0.282	0.277	0.272	0.268	0.263	0.258	0.253	0.243	0.239
13	**0.220**	0.272	0.267	0.262	0.258	0.253	0.248	0.243	0.238	0.233	0.229	0.224	0.215	0.211
13.5	**0.196**	0.246	0.241	0.237	0.232	0.227	0.222	0.218	0.213	0.208	0.204	0.200	0.192	0.188
14	**0.175**	0.223	0.218	0.213	0.209	0.204	0.199	0.195	0.191	0.186	0.182	0.179	0.172	0.168
14.5	**0.157**	0.202	0.197	0.192	0.188	0.183	0.179	0.175	0.171	0.167	0.164	0.161	0.154	0.151
15	**0.141**	0.181	0.176	0.172	0.168	0.164	0.160	0.157	0.154	0.150	0.147	0.144	0.139	0.136
15.5	**0.128**	0.164	0.160	0.156	0.152	0.148	0.145	0.142	0.139	0.136	0.133	0.131	0.126	0.124
16	**0.117**	0.149	0.145	0.142	0.138	0.135	0.132	0.129	0.127	0.124	0.121	0.119	0.115	0.112
16.5	**0.107**	0.135	0.132	0.129	0.126	0.123	0.121	0.118	0.116	0.113	0.111	0.109	0.105	0.103
17	**0.098**	0.124	0.121	0.118	0.115	0.113	0.110	0.108	0.106	0.104	0.102	0.100	0.096	0.094
17.5	**0.090**	0.114	0.111	0.109	0.106	0.104	0.101	0.099	0.097	0.095	0.093	0.092	0.088	0.087
18	**0.083**	0.105	0.102	0.100	0.098	0.095	0.093	0.092	0.090	0.088	0.086	0.085	0.082	0.080
18.5	**0.077**	0.097	0.094	0.092	0.090	0.088	0.086	0.085	0.083	0.081	0.080	0.078	0.075	0.074
19	**0.072**	0.090	0.088	0.086	0.084	0.082	0.081	0.079	0.077	0.076	0.074	0.073	0.070	0.069
19.5	**0.067**	0.083	0.082	0.080	0.078	0.076	0.075	0.073	0.072	0.070	0.069	0.068	0.066	0.064
20	**0.062**	0.078	0.076	0.074	0.073	0.071	0.070	0.068	0.067	0.066	0.064	0.063	0.061	0.060

Table 12-8: V100-1.8 MW C_t values, Noise Mode 2.

12.3.3 V100-1.8 MW Sound Power Levels, Noise Mode 2

V100-1.8 MW Sound Power Level at Hub Height, Noise Mode 2		
Conditions for Sound Power Level:	**Measurement standard IEC 61400-11 Ed. 2.** **Wind shear: 0.15** **Maximum turbulence at 10 metre height: 16%** **Inflow angle (vertical): 0 ± 2°** **Air density: 1.225 kg/m^3**	
Hub Height	**80 m**	**95 m**
LwA @ 3 m/s (10 m above ground) [dBA] Wind speed at hub height [m/s]	94.0 4.2	94.1 4.3
LwA @ 4 m/s (10 m above ground) [dBA] Wind speed at hub height [m/s]	96.1 5.6	96.5 5.7
LwA @ 5 m/s (10 m above ground) [dBA] Wind speed at hub height [m/s]	100.0 7.0	100.6 7.2
LwA @ 6 m/s (10 m above ground) [dBA] Wind speed at hub height [m/s]	102.9 8.4	102.9 8.6
LwA @ 7 m/s (10 m above ground) [dBA] Wind speed at hub height [m/s]	103.0 9.8	103.0 10.0
LwA @ 8 m/s (10 m above ground) [dBA] Wind speed at hub height [m/s]	103.0 11.2	103.0 11.5
LwA @ 9 m/s (10 m above ground) [dBA] Wind speed at hub height [m/s]	103.0 12.6	103.0 12.9
LwA @ 10 m/s (10 m above ground) [dBA] Wind speed at hub height [m/s]	103.0 13.9	103.0 14.3
LwA @ 11 m/s (10 m above ground) [dBA] Wind speed at hub height [m/s]	103.0 15.3	103.0 15.8
LwA @ 12 m/s (10 m above ground) [dBA] Wind speed at hub height [m/s]	103.0 16.7	103.0 17.2
LwA @ 13 m/s (10 m above ground) [dBA] Wind speed at hub height [m/s]	103.0 18.1	103.0 18.6

Table 12-9: V100-1.8 MW Sound power level at hub height, Noise Mode 2.

12.4 V100-2.0 MW Power Mode

12.4.1 Power Curve, Noise Mode 0

V100-2.0 MW, Power Mode 0, Power Curves														
	Air density kg/m^3													
Wind Speed [m/s]	**1.225**	**0.95**	**0.975**	**1.0**	**1.025**	**1.05**	**1.075**	**1.1**	**1.125**	**1.15**	**1.175**	**1.2**	**1.25**	**1.275**
3	**13**	9	9	10	10	10	11	11	12	12	12	13	14	14
3.5	**51**	34	35	37	39	40	42	43	45	46	48	50	53	54
4	**107**	78	80	83	86	89	91	94	97	99	102	105	110	113
4.5	**175**	131	135	139	143	147	151	155	159	163	167	171	179	183
5	**253**	193	198	204	209	215	220	226	231	237	242	248	259	264
5.5	**346**	265	272	279	287	294	302	309	316	324	331	338	353	360
6	**454**	349	359	368	378	387	397	406	416	425	435	444	463	472
6.5	**584**	447	459	472	484	497	509	522	534	547	559	571	596	609
7	**738**	567	582	598	613	629	645	660	676	691	707	722	753	768
7.5	**912**	703	722	741	760	779	798	817	836	855	874	893	931	950
8	**1109**	858	881	904	927	950	972	995	1018	1041	1063	1086	1131	1154
8.5	**1321**	1029	1056	1083	1110	1137	1164	1190	1216	1243	1269	1295	1347	1372
9	**1538**	1212	1243	1273	1304	1334	1364	1393	1423	1452	1481	1510	1565	1593
9.5	**1734**	1398	1432	1465	1498	1531	1562	1593	1623	1654	1680	1707	1756	1779
10	**1873**	1582	1615	1648	1681	1714	1739	1765	1790	1816	1835	1854	1887	1902
10.5	**1951**	1746	1772	1798	1824	1850	1867	1884	1901	1918	1929	1940	1959	1966
11	**1984**	1867	1885	1902	1919	1937	1945	1954	1962	1971	1975	1979	1986	1989
11.5	**1995**	1942	1951	1959	1968	1976	1980	1983	1987	1990	1992	1993	1996	1997
12	**2000**	1977	1980	1984	1988	1991	1993	1994	1996	1997	1998	1999	2000	2000
12.5	**2000**	1991	1993	1994	1996	1997	1998	1999	1999	2000	2000	2000	2000	2000
13	**2000**	1997	1998	1999	1999	2000	2000	2000	2000	2000	2000	2000	2000	2000
13.5	**2000**	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
14	**2000**	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
14.5	**2000**	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
15	**2000**	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
15.5	**2000**	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
16	**2000**	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
16.5	**2000**	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
17	**2000**	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
17.5	**2000**	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
18	**2000**	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
18.5	**2000**	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
19	**2000**	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
19.5	**2000**	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
20	**2000**	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000

Table 12-10: V100-2.0 MW Power Curve, Noise Mode 0.

12.4.2 V100-2.0 MW C_t Values, Noise Mode 0

V100-2.0 MW, Power Mode 0. C_t Values														
	Air density kg/m^3													
Wind speed [m/s]	**1.225**	**0.95**	**0.975**	**1.0**	**1.025**	**1.05**	**1.075**	**1.1**	**1.125**	**1.15**	**1.175**	**1.2**	**1.25**	**1.275**
3	**0.868**	0.870	0.869	0.869	0.869	0.869	0.869	0.869	0.869	0.869	0.869	0.868	0.868	0.868
3.5	**0.890**	0.890	0.890	0.890	0.890	0.890	0.890	0.890	0.890	0.890	0.890	0.890	0.890	0.890
4	**0.882**	0.881	0.881	0.881	0.882	0.882	0.882	0.882	0.882	0.882	0.882	0.882	0.882	0.882
4.5	**0.854**	0.854	0.854	0.854	0.854	0.854	0.854	0.854	0.854	0.854	0.854	0.854	0.854	0.854
5	**0.825**	0.824	0.825	0.825	0.825	0.825	0.825	0.825	0.825	0.825	0.825	0.825	0.825	0.825
5.5	**0.808**	0.807	0.807	0.807	0.807	0.807	0.807	0.807	0.808	0.808	0.808	0.808	0.808	0.808
6	**0.802**	0.801	0.801	0.801	0.801	0.801	0.801	0.802	0.802	0.802	0.802	0.802	0.802	0.802
6.5	**0.818**	0.817	0.817	0.817	0.817	0.817	0.818	0.818	0.818	0.818	0.818	0.818	0.818	0.818
7	**0.808**	0.807	0.807	0.807	0.807	0.808	0.808	0.808	0.808	0.808	0.808	0.808	0.808	0.808
7.5	**0.804**	0.803	0.803	0.803	0.803	0.803	0.803	0.804	0.804	0.804	0.804	0.804	0.804	0.804
8	**0.796**	0.800	0.800	0.800	0.799	0.799	0.799	0.799	0.798	0.798	0.797	0.797	0.795	0.795
8.5	**0.771**	0.787	0.786	0.785	0.784	0.783	0.781	0.780	0.778	0.777	0.775	0.773	0.769	0.768
9	**0.728**	0.759	0.756	0.754	0.751	0.749	0.746	0.743	0.740	0.738	0.735	0.731	0.725	0.721
9.5	**0.666**	0.716	0.712	0.708	0.705	0.701	0.697	0.692	0.688	0.683	0.678	0.672	0.660	0.653
10	**0.590**	0.668	0.662	0.657	0.651	0.646	0.638	0.631	0.624	0.616	0.607	0.599	0.581	0.571
10.5	**0.510**	0.614	0.606	0.597	0.588	0.580	0.570	0.560	0.550	0.540	0.530	0.520	0.500	0.490
11	**0.434**	0.553	0.542	0.531	0.520	0.510	0.498	0.487	0.476	0.465	0.455	0.445	0.425	0.416
11.5	**0.372**	0.488	0.476	0.464	0.452	0.440	0.430	0.419	0.409	0.399	0.390	0.381	0.364	0.356
12	**0.321**	0.424	0.413	0.402	0.391	0.380	0.371	0.362	0.353	0.344	0.336	0.329	0.314	0.308
12.5	**0.280**	0.369	0.359	0.350	0.340	0.330	0.323	0.315	0.307	0.299	0.293	0.286	0.274	0.268
13	**0.246**	0.323	0.315	0.306	0.298	0.290	0.283	0.276	0.270	0.263	0.257	0.252	0.241	0.236
13.5	**0.218**	0.285	0.278	0.270	0.263	0.256	0.250	0.244	0.239	0.233	0.228	0.223	0.214	0.210
14	**0.195**	0.253	0.246	0.240	0.234	0.228	0.222	0.217	0.212	0.207	0.203	0.199	0.191	0.187
14.5	**0.175**	0.226	0.220	0.215	0.209	0.204	0.199	0.195	0.190	0.186	0.182	0.178	0.171	0.168
15	**0.157**	0.202	0.197	0.192	0.188	0.183	0.179	0.175	0.171	0.167	0.164	0.160	0.154	0.151
15.5	**0.142**	0.183	0.178	0.174	0.170	0.165	0.162	0.158	0.155	0.151	0.148	0.145	0.140	0.137
16	**0.129**	0.165	0.162	0.158	0.154	0.150	0.147	0.144	0.141	0.137	0.135	0.132	0.127	0.125
16.5	**0.118**	0.151	0.147	0.144	0.140	0.137	0.134	0.131	0.128	0.125	0.123	0.121	0.116	0.114
17	**0.108**	0.138	0.135	0.131	0.128	0.125	0.123	0.120	0.117	0.115	0.113	0.110	0.106	0.104
17.5	**0.099**	0.126	0.123	0.121	0.118	0.115	0.112	0.110	0.108	0.105	0.103	0.101	0.098	0.096
18	**0.092**	0.116	0.114	0.111	0.108	0.106	0.104	0.101	0.099	0.097	0.095	0.094	0.090	0.088
18.5	**0.085**	0.107	0.105	0.102	0.100	0.098	0.096	0.094	0.092	0.090	0.088	0.086	0.083	0.082
19	**0.079**	0.099	0.097	0.095	0.093	0.091	0.089	0.087	0.085	0.083	0.082	0.080	0.077	0.076
19.5	**0.073**	0.092	0.090	0.088	0.086	0.084	0.082	0.081	0.079	0.077	0.076	0.075	0.072	0.071
20	**0.068**	0.086	0.084	0.082	0.080	0.078	0.077	0.075	0.074	0.072	0.071	0.070	0.067	0.066

Table 12-11: V100-2.0 MW C_t values, Noise Mode 0.

12.4.3 V100-2.0 MW Sound Power Level, Noise Mode 0

V100-2.0 MW Sound Power Level at Hub Height, Power Mode 0		
Conditions for Sound Power Level:	**Measurement standard IEC 61400-11 Ed. 2.** **Wind shear: 0.15** **Maximum turbulence at 10 metre height: 16%** **Inflow angle (vertical): 0 ± 2°** **Air density: 1.225 kg/m^3**	
Hub Height	**80 m**	**95 m**
LwA @ 3 m/s (10 m above ground) [dBA] Wind speed at hub height [m/s]	94.0 4.2	94.1 4.3
LwA @ 4 m/s (10 m above ground) [dBA] Wind speed at hub height [m/s]	96.2 5.6	96.6 5.7
LwA @ 5 m/s (10 m above ground) [dBA] Wind speed at hub height [m/s]	100.1 7.0	100.7 7.2
LwA @ 6 m/s (10 m above ground) [dBA] Wind speed at hub height [m/s]	103.9 8.4	104.4 8.6
LwA @ 7 m/s (10 m above ground) [dBA] Wind speed at hub height [m/s]	105.0 9.8	105.0 10.0
LwA @ 8 m/s (10 m above ground) [dBA] Wind speed at hub height [m/s]	105.0 11.2	105.0 11.5
LwA @ 9 m/s (10 m above ground) [dBA] Wind speed at hub height [m/s]	105.0 12.6	105.0 12.9
LwA @ 10 m/s (10 m above ground) [dBA] Wind speed at hub height [m/s]	105.0 13.9	105.0 14.3
LwA @ 11 m/s (10 m above ground) [dBA] Wind speed at hub height [m/s]	105.0 15.3	105.0 15.8
LwA @ 12 m/s (10 m above ground) [dBA] Wind speed at hub height [m/s]	105.0 16.7	105.0 17.2
LwA @ 13 m/s (10 m above ground) [dBA] Wind speed at hub height [m/s]	105.0 18.1	105.0 18.6

Table 12-12: V100-2.0 MW Sound power level at hub height, Noise Mode 0.