Draft For Comment

MORRISON HERSHFIELD
Suite 600, 235 Yorkland Boulevard
Toronto, Ontario M2J 1T1
Tel: 416 499 3110
Fax: 416 499 9658
morrisonhershfield.com

Project Number: **1104037.00**

Project Title: **HAF WIND ENERGY PROJECT**

Report: **001-R03-1104037**

Title: **WIND TURBINE SPECIFICATION REPORT**

Client: **IPC Energy**
2550 Argentia Road Suite 105
Mississauga, Ontario
L5N 5R1

Date: **April, 2012**
(Draft for public and agency review)

Prepared By Morrison Hershfield Limited

Table of Contents

1.0 Wind Turbine Specifications Report 1
1.1 Technical Specifications 1
1.2 Acoustic Emissions Data 3
1.3 Wind Turbine Locations 5
1.4 Qualifications and Limitations 6

Tables

Table 1.1: Summary of Technical Specifications of the Vestas V100-1.8MW
Table 1-2a: Sound Power Level Ratings for Mode 0
Table 1-2b: Sound Power Level Ratings for Mode 1
Table 1-2c: Sound Power Level Ratings for Mode 2
Table 1-3: Octave Band Spectra
Table 1-4: Coordinates of Each Turbine

Appendices

Appendix 1: Manufacturer Technical Data

REA Package Reference Tabs

Tab 1: Study Area Map
Tab 2: Site Plan
Tab 3: Land-Use Maps

1.0 Wind Turbine Specifications Report

The HAF Wind Energy Project ("the Project") Wind Turbine Specifications Report has been prepared in accordance with the requirements of the Ministry of the Environment's Renewable Energy Approvals Regulation ("the Regulation"), O.Reg 359/09, specifically with consideration of *Item 13* of the requirements outlined in *Table 1* of the Regulation.

The proposed HAF Wind Energy Project is to be situated in the Township of West Lincoln, in the Niagara Region of Ontario. The Project would consist of five (5) Vestas V-100 1.8 megawatt wind turbines producing a nameplate capacity of 9.0 megawatts. If approved, the wind turbines would be erected for the purpose of capturing energy from the wind, a renewable resource, and converting it into clean, useable electricity. This electricity will be transported to consumers via interconnection facilities, including transformers and distribution lines. The footprint of these facilities is captured and described in reports prepared for this Renewable Energy Approval (REA).

The purpose of this report is to provide technical information on the turbines to be used for the proposed Project. The turbine model was selected based upon its technical performance, design characteristics, acoustic properties, power output, and site specific considerations.

1.1 Technical Specifications

The Vestas V100-1.8 MW wind turbine is a pitch regulated upwind turbine with active yaw and a three-blade rotor. The Vestas V100-1.8 MW turbine has a rotor diameter of 100 m with a generator rated at 1.8 MW. The turbine utilizes a microprocessor pitch control system called OptiTip®. With these features the wind turbine is able to optimize power output at different wind speeds.

A summary of the technical specifications is presented in **Table 1.1**with additional information provided by the manufacturer is included in **Appendix 1**.

Table 1.1a: Summary of Technical Specifications of the Vestas V100-1.8MW

Specification	Vestas V100-1.8MW
Nameplate Capacity	1.8 Megawatt
Hub Height (above grade)	95 m
Rotator Diameter	100 m
Blade Length	49 m
Swept Area	7850 m^2
Minimum Wind Speed (cut-in speed)	4.0 m/s
Maximum Wind Speed (cut-out speed)	20.0 m/s
Dynamic Rotational Speed Range	9.3 rpm to 16.6 rpm
Actual Rotational Speed	14.9 rpm

Each Vestas V100 turbine has a nameplate capacity of 1.8 MW and will be built to a hub height of 95 meters. The rotor diameter is 100 meters with swept area of 7850 m2.

The minimum operational wind speed (cut-in speed) is 4.0 m/s with a maximum operational speed (cut-out speed) of 20.0 m/s.

The V-100 Turbine is erected on a tabular steel tower which holds the nacelle at 95 meters above the ground. The nacelle houses the hub and electrical components. Each blade is constructed of light weight airfoil shells bonded to supporting beams and connect to the hub forming a 100 meter rotor. The generator is asynchronous with wound rotor, slip rings and VCUS. The turbine's operational envelope is -20° to +40° C.

Table 1.1b summarizes the Wind Turbine General Specifications.

Table 1.1b: Wind Turbine General Specifications	
	Operational Envelope: **-20° to +40° C**
Rotor	Rotor Diameter: **100m**
	Swept Area: **7850m²**
	Speed, Dynamic Operation Range: **9.3 – 16.6 rpm**
	Rotational Direction: **Clockwise** (front view)
Tower	Type: **tubular steel tower**
	Hub: **95m**
Electrical	Frequency: **60 Hz**
	Rated Power: **1.8 MW**
	Generator: **Asynchronous with wound rotor, slip rings and VCUS**
Blade	Type: **airfoil shells bonded to supporting beam**
	Length: **49m**
	Max Chord: **3.9m**
Nacelle	Height for Transport: **4.0 m**
	Height Installed: **5.4 m**
	Width: **3.4 m**
	Length: **10.4 m**
Hub	Material: **cast ball shell hub**
	Height: **95m**
	Diameter: **3.3 m**

1.2 Acoustic Emissions Data

The V100 1.8 MW turbine model has a maximum sound power rating of **105.00 dBA**. Additional information on the acoustic data can be found in **Tables 1.2a, 1.2b, 1.2c,** and **1.3**. These tables summarize the wind turbine specifications provided in the Manufacture Technical Details provided in **Appendix 1**.

Table 1-2a provides the Sound Power Level Ratings (dBA) for **Mode 0** at a Hub Height of **95 meters**. The table shows the conditions for sound power levels at speeds of **3 m/s** to **13 m/s** at **10 meters** with the corresponding wind speed at hub height (HH). The sound power rating does not exceed 105.00 dBA.

Table 1-2a: Sound Power Level Ratings for Mode 0

Conditions for Sound Power Level	Hub Height 95 meters	Wind speed at hh [m/sec]
LwA @ **3 m/s** (10 m above ground) [dBA]	93.8	4.3
LwA @ **4 m/s** (10 m above ground) [dBA]	96.4	5.7
LwA @ **5 m/s** (10 m above ground) [dBA]	100.7	7.2
LwA @ **6 m/s** (10 m above ground) [dBA]	104.4	8.6
LwA @ **7 m/s** (10 m above ground) [dBA]	105.0	10.0
LwA @ **8 m/s** (10 m above ground) [dBA]	105.0	11.5
LwA @ **9 m/s** (10 m above ground) [dBA]	105.0	12.9
LwA @ **10 m/s** (10 m above ground) [dBA]	105.0	14.3
LwA @ **11 m/s** (10 m above ground) [dBA]	105.0	15.8
LwA @ **12 m/s** (10 m above ground) [dBA]	105.0	17.2
LwA @ **13 m/s** (10 m above ground) [dBA]	105.0	18.6

Table 1-2b (below) provides the Sound Power Level Ratings (dBA) for **Mode 1** at a Hub Height of **95 meters**. The table shows the conditions for sound power levels at speeds of **3 m/s** to **13 m/s** at **10 meters** with the corresponding wind speed at hub height (HH). The sound power rating does not exceed 105.00 dBA.

Table 1-2b: Sound Power Level Ratings for Mode 1		
Conditions for Sound Power Level	**Hub Height 95 meters**	**Wind speed at hh [m/sec]**
LwA @ **3 m/s** (10 m above ground) [dBA]	93.7	4.3
LwA @ **4 m/s** (10 m above ground) [dBA]	95.7	5.7
LwA @ **5 m/s** (10 m above ground) [dBA]	99.7	7.2
LwA @ **6 m/s** (10 m above ground) [dBA]	103.4	8.6
LwA @ **7 m/s** (10 m above ground) [dBA]	105.0	10.0
LwA @ **8 m/s** (10 m above ground) [dBA]	105.0	11.5
LwA @ **9 m/s** (10 m above ground) [dBA]	105.0	12.9
LwA @ **10 m/s** (10 m above ground) [dBA]	105.0	14.3
LwA @ **11 m/s** (10 m above ground) [dBA]	105.0	15.8
LwA @ **12 m/s** (10 m above ground) [dBA]	105.0	17.2
LwA @ **13 m/s** (10 m above ground) [dBA]	105.0	18.6

Table 1-2c provides the Sound Power Level Ratings (dBA) for **Mode 2** at a Hub Height of **95 meters**. The table shows the conditions for sound power levels at speeds of **3 m/s** to **13 m/s** at **10 meters** with the corresponding wind speed at hub height (HH). The sound power rating does not exceed 105.00 dBA.

Table 1-2c: Sound Power Level Ratings for Mode 2		
Conditions for Sound Power Level	**Hub Height 95 meters**	**Wind speed at hh [m/sec]**
LwA @ **3 m/s** (10 m above ground) [dBA]	93.8	4.3
LwA @ **4 m/s** (10 m above ground) [dBA]	96.4	5.7
LwA @ **5 m/s** (10 m above ground) [dBA]	100.7	7.2
LwA @ **6 m/s** (10 m above ground) [dBA]	103.0	8.6
LwA @ **7 m/s** (10 m above ground) [dBA]	103.0	10.0
LwA @ **8 m/s** (10 m above ground) [dBA]	103.0	11.5
LwA @ **9 m/s** (10 m above ground) [dBA]	103.0	12.9
LwA @ **10 m/s** (10 m above ground) [dBA]	103.0	14.3
LwA @ **11 m/s** (10 m above ground) [dBA]	103.0	15.8
LwA @ **12 m/s** (10 m above ground) [dBA]	103.0	17.2
LwA @ **13 m/s** (10 m above ground) [dBA]	103.0	18.6

Table 1-3 provides the Octave Band Spectra showing Octave in Hz from **16** Hz to **8000 Hz** with the corresponding Sound Power Level in dB(A). Sound Power Level does not exceed **99.7 dB**.

Table 1-3: Octave Band Spectra

Wind Speed@10m [m/s]	3	4	5	6	7	8	9	10	11	12	13	14
16Hz [dB(A)]	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
31.5Hz [dB(A)]	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN
63Hz [dB(A)]	NaN	NaN	NaN	85.2	87.4	87.1	86.7	86.6	NaN	NaN	NaN	NaN
125Hz [dB(A)]	NaN	NaN	NaN	89.6	92	91.7	91.3	91.4	NaN	NaN	NaN	NaN
250Hz [dB(A)]	NaN	NaN	NaN	93	94.7	94.2	93.6	93.5	NaN	NaN	NaN	NaN
500Hz [dB(A)]	NaN	NaN	NaN	95.4	97.1	96.7	96.1	96.1	NaN	NaN	NaN	NaN
1000Hz [dB(A)]	NaN	NaN	NaN	98.2	99.7	99.5	99	99.1	NaN	NaN	NaN	NaN
2000Hz [dB(A)]	NaN	NaN	NaN	96.6	98.2	98.4	98.2	98.2	NaN	NaN	NaN	NaN
4000Hz [dB(A)]	NaN	NaN	NaN	94.6	96.6	97.2	98.7	98.6	NaN	NaN	NaN	NaN
8000Hz [dB(A)]	NaN	NaN	NaN	85.4	89.8	90.3	91.4	92.3	NaN	NaN	NaN	NaN

Table 1-3 Notes:

1. “NAN” indicates data not available due to insufficient data collection at this wind speed.
2. Disclaimers from Vestas: The values are valid for the A-weighted sound power levels
   Octave band values must be regarded as informative
   Site specific values are not warranted
3. Measurement standard ICE 6140011:2002, using amendments procedure above 95% RP

1.3 Wind Turbine Locations

The coordinates for each wind turbine in the proposed HAF Wind Energy Project are presented in **Table 1-4**, below.

Table 1-4: Coordinates of Each Turbine (NAD 83, UTM Zone 17)

Turbine Number	Northing	Easting
1	604718	4775553
2	604889	4775173
3	606291	4774905
4	604359	4774307
5	606233	4773420

In accordance with Ministry of Environment (MOE) setback requirements all project turbines will be located a minimum of 550 metres from the nearest non-participating noise receptor and will be sited a minimum of 95 metres (hub height) from non-participating property line boundaries. In addition, all turbines will be located a minimum of 59 metres (length of the turbine blade plus 10 metres) from the boundary of any right-of-way for any public road or railway to ensure compliance with MOE setback requirements.

1.4 Qualifications and Limitations

This summary report was produced, in part, to fulfill the requirements for the Turbine Specifications Report for the Renewable Energy Approval (REA). The contents of this document have been produced using the requirements outlined in O.Reg 359/09 as well as other applicable Acts and Regulations governing these projects.

Morrison Hershfield Limited's assessment was made in accordance with guidelines, regulations and procedures believed to be current at this time. Changes in guidelines, regulations and policies can occur at the discretion of the government and such changes could affect this report.

Morrison Hershfield Limited and the consulting team retained for this Project have prepared this report in accordance with information provided by its Client and their representatives. While we may have referred to and made use of this information and reporting, we assume no liability for the accuracy of this information.

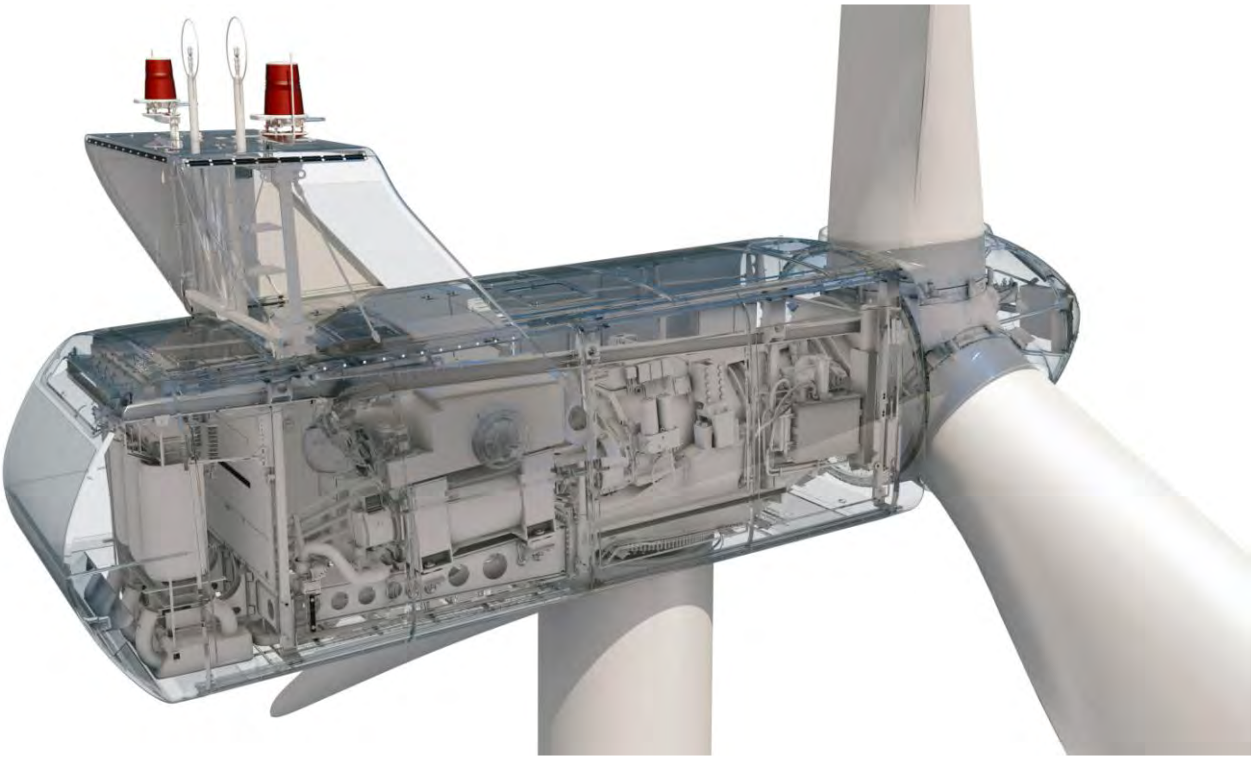
Appendix 1: Manufacturer Technical Details

(As provided by Vestas to Vineland Power Inc.)

Class 1
Document no.: 0004-3053 V07
2010-11-22

General Specification

V100–1.8 MW VCUS



Vestas Wind Systems A/S · Alsvej 21 · 8940 Randers SV · Denmark · www.vestas.com

Table of Contents

1 General Description ... 5
2 Mechanical Design ... 5
2.1 Rotor ... 5
2.2 Blades ... 5
2.3 Blade Bearing ... 6
2.4 Pitch System ... 6
2.5 Hub ... 7
2.6 Main Shaft ... 7
2.7 Bearing Housing ... 7
2.8 Main Bearings ... 7
2.9 Gearbox ... 8
2.10 Generator Bearings ... 8
2.11 High-Speed Shaft Coupling ... 8
2.12 Yaw System ... 9
2.13 Crane ... 9
2.14 Tower Structure ... 9
2.15 Nacelle Bedplate and Cover ... 10
2.16 Cooling ... 11
2.17 Water Cooling System ... 11
2.18 Gearbox Cooling ... 11
2.19 Hydraulic Cooling ... 12
2.20 VCUS Converter Cooling ... 13
2.21 Generator Cooling ... 13
2.22 HV Transformer Cooling ... 13
2.23 Nacelle Conditioning ... 14
3 Electrical Design ... 14
3.1 Generator ... 14
3.2 HV Cables ... 15
3.3 Transformer ... 16
3.4 Converter ... 16
3.5 AUX System ... 17
3.6 Wind Sensors ... 17
3.7 Turbine Controller ... 17
3.8 Uninterruptible Power Supply (UPS) ... 18
4 Turbine Protection Systems ... 19
4.1 Braking Concept ... 19
4.2 Short Circuit Protections ... 19
4.3 Overspeed Protection ... 19
4.4 EMC System ... 20
4.5 Lightning System ... 20
4.6 Earthing (also Known as Grounding) ... 20
4.7 Corrosion Protection ... 21
5 Safety ... 21
5.1 Access ... 21
5.2 Escape ... 21
5.3 Rooms/Working Areas ... 21
5.4 Platforms, Standing and Working Places ... 22
5.5 Climbing Facilities ... 22
5.6 Moving Parts, Guards and Blocking Devices ... 22
5.7 Lighting ... 22
5.8 Noise ... 22
5.9 Emergency Stop ... 22

5.10 Power Disconnection ... 23
5.11 Fire Protection/First Aid ... 23
5.12 Warning Signs ... 23
5.13 Manuals and Warnings ... 23
6 Environment ... 23
6.1 Chemicals ... 23
7 Approvals, Certificates and Design Codes ... 24
7.1 Type Approvals ... 24
7.2 Design Codes – Structural Design ... 24
7.3 Design Codes – Mechanical Equipment ... 25
7.4 Design Codes – Electrical Equipment ... 25
7.5 Design Codes – I/O Network System ... 26
7.6 Design Codes – EMC System ... 26
7.7 Design Codes – Lightning Protection ... 27
7.8 Design Codes – Earthing ... 27
8 Colour and Surface Treatment ... 27
8.1 Nacelle Colour and Surface Treatment ... 27
8.2 Tower Colour and Surface Treatment ... 28
8.3 Blades Colour ... 28
9 Operational Envelope and Performance Guidelines ... 28
9.1 Climate and Site Conditions ... 28
9.1.1 Complex Terrain ... 29
9.1.2 Altitude ... 29
9.1.3 Wind Farm Layout ... 29
9.2 Operational Envelope – Temperature and Wind ... 29
9.3 Operational Envelope – Grid Connection * ... 30
9.4 Performance – Fault Ride Through ... 30
9.5 Current Contribution ... 31
9.6 Performance – Multiple Voltage Dips ... 32
9.7 Performance – Active Power Control ... 32
9.8 Performance – Frequency Control ... 32
9.9 Performance – Own Consumption ... 33
9.10 Operational Envelope Conditions for Power Curve, C_t Values (at Hub Height) ... 33
10 Drawings ... 34
10.1 Structural Design – Illustration of Outer Dimensions ... 34
10.2 Structural Design – Side-View Drawing ... 35
11 General Reservations, Notes and Disclaimers ... 36
12 Appendices ... 37
12.1 Mode 0 ... 37
12.1.1 Power Curve, Noise Mode 0 ... 37
12.1.2 Ct Values, Noise Mode 0 ... 39
12.1.3 Noise Curve, Noise Mode 0 ... 41
12.2 Mode 1 ... 42
12.2.1 Power Curve, Noise Mode 1 ... 42
12.2.2 Ct Values, Noise Mode 1 ... 44
12.2.3 Noise Curve, Noise Mode 1 ... 46
12.3 Mode 2 ... 47
12.3.1 Power Curve, Noise Mode 2 ... 47
12.3.2 Ct Values, Noise Mode 2 ... 49
12.3.3 Noise Curve, Noise Mode 2 ... 51

Buyer acknowledges that these general specifications are for Buyer's informational purposes only and do not create or constitute a warranty, guarantee, promise, commitment, or other representation by supplier, all of which are disclaimed by supplier except to the extent expressly provided by supplier in writing elsewhere.

See section 11 General Reservations, Notes and Disclaimers, p. 36 for general reservations, notes, and disclaimers applicable to these general specifications.

1 General Description

The Vestas V100-1.8 MW wind turbine is a pitch regulated upwind turbine with active yaw and a three-blade rotor. The Vestas V100-1.8 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 the Variable Speed concepts (VCUS: Vestas Converter Unity System). With these features, the wind turbine is able to operate the rotor at variable speed (rpm), helping to maintain the output at or near rated power.

2 Mechanical Design

2.1 Rotor

The V100-1.8 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 fibre glass and consist of two airfoil shells bonded to a supporting beam.

PP Blades	
Type Description	Airfoil shells bonded to supporting beam
Blade Length	49 m
Material	Fibre glass reinforced epoxy and carbon fibres
Blade Connection	Steel roots inserted
Air Foils	RISØ P + FFA –W3

PP Blades	
Chord	3.9 m
Blade Root Outer Diameter	1.88 m
PCD of Steel Root Inserts	1.80 m
Blade Tip (R49)	0.54 m
Twist (Blade root/blade tip)	24.5°/-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/min.
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 pitch cylinder.

Hub	
Type	Cast ball shell hub
Material	Cast iron EN GJS 400-18U-LT / EN1560

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 / EN1560

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 torque and revolutions 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	1:92.8 nominal
Cooling	Oil pump with oil cooler
Oil heater	2 kW
Maximum Gear Oil Temp	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 misalignments between gearbox and generator. The coupling consists of two composite discs and an intermediate tube with two aluminium flanges and a fibre glass 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, which 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 information of the wind direction 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 a mechanical connection.

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 a distance from the tower top flange to the centre of the hub of 1.70 m.

Tower Structure	
Type Description	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 (onshore) data.

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

2.15 Nacelle Bedplate and Cover

The nacelle cover is made of fibre glass. 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 which 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, which 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 foundation for controller panels, generator and transformer.

Type Description	Material
Nacelle Cover	GRP
Bedplate Front	Cast iron EN GJS 400-18U-LT / EN1560
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 VCUS 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	Natural air	No (Yes 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)
VCUS	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 as minor contributors to nacelle thermodynamics.

2.17 Water Cooling System

The water cooling system is designed as semi-closed systems (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 VCUS converter.

The water cooling system is equipped with a three-way thermostatic valve. The valve is closed (total water flow bypassing the water cooler) if the temperature of the cooling water is below 35°C and fully open (total water flow led 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. 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/min.
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/min.
Oil inlet temperature	80°C
Number of passes	2
Cooling capacity	41.5 kW
Water Circuit	
Nominal water flow	Approximately 150 l/min. (50% glycol)
Water inlet temperature	Maximum 54°C
Number of passes	1
Heat load	66 kW

Table 2-18: Cooling, gearbox 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/min.
Oil inlet temperature	66°C
Cooling capacity	10.28 kW
Water Circuit	
Nominal water flow	Approximately 45 l/min. (50% glycol)
Water inlet temperature	Maximum 54°C
Heat load	10.28 kW

Table 2-19: Cooling, hydraulic data.

2.20 VCUS Converter Cooling

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

Converter Cooling	
Nominal water flow	Approximately 45 l/min. (50% glycol)
Water inlet pressure	Maximum 2.0 bar
Water inlet temperature	Maximum 54°C
Cooling capacity	10 kW

Table 2-20: Cooling, converter data.

2.21 Generator Cooling

The generator cooling systems consists of an air-to-air cooler mounted on the top of 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	60 kW

Table 2-21: Cooling, generator data.

2.22 HV Transformer Cooling

The transformer is equipped with forced air cooling. The cooling system consists of a central fan that is 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: Cooling, transformer 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:

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. 13.

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, removing hot air from the nacelle, which is generated by mechanical and electrical equipment.

Nacelle Cooling	
Nominal air flow	1.2 m^3/s
Air inlet temperature	Maximum 50°C

Table 2-23: Cooling, nacelle data.

Nacelle Heating	
Rated power	2 x 6 kW

Table 2-24: Heating, nacelle 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 Unity System (VCUS) via a slip ring system. The generator is an air-to-air cooled generator with an internal and external cooling circuit. The external circuit uses air from the nacelle and expels it as exhaust out the rear end of the nacelle.

The generator has six 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 VCUS control.

Generator	
Type Description	Asynchronous with wound rotor, slip rings and VCUS
Rated Power (PN)	1.8 MW
Rated Apparent Power	1.8 MVA (Cosφ = 1.00)
Frequency	60 Hz
Voltage, Generator	690 Vac
Voltage, Converter	480 Vac
Number of Poles	6
Winding Type (Stator/Rotor)	Form/Form
Winding Connection, Stator	Star/Delta
Rated Efficiency (Generator only)	> 96.5%
Power Factor (cos)	1.0
Over Speed Limit according to IEC (2 minute)	2400 rpm
Vibration Level	≤ 1.8 mm/s
Weight	Approximately 8,100 kg
Generator Bearing - Temperature	2 PT100 sensors
Generator Stator Windings - Temperature	3 PT100 sensors placed at hot spots and 3 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 transformer is located in a separate locked room in the nacelle with surge arresters mounted on the high-voltage side of the transformer. The transformer is a two-winding, three-phase, dry-type transformer. The windings are delta-connected on the high-voltage side unless otherwise specified.

The low-voltage windings have a voltage of 690 V and a tapping at 480 V and are star-connected. The 690 V and 480 V systems in the nacelle are TN-systems, which means the star point is connected to earth.

Transformer	
Type Description	Dry-type cast resin
Primary Voltage	6.0-35.0 kV
Rated Power	2100 kVA
Secondary Voltage 1	690 V
Rated Power 1 at 690 V	1900 kVA
Secondary Voltage 2	480 V
Rated Power 2 at 480 V	200 kVA
Vector Group	Dyn5 (option YNyn0)
Frequency	60 Hz
HV-Tappings	± 2 x 2.5% off-circuit
Insulation Class	F
Climate Class	C2
Environmental Class	E2
Fire Behaviour Class	F1

Table 3-3: Transformer data.

3.4 Converter

The converter controls the energy conversion in the generator. The VCUS 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	1344 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 110 V power sockets are supplied from a 690/110 V transformer.

Power Sockets	
Single Phase	110 V (20 A)
Three Phase	690 V Crane (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
Built-in Heat	99 W

Table 3-6: Wind sensor data.

3.7 Turbine Controller

The turbine is controlled and monitored by the System 3500 controller hardware and Vestas 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. rpm, azimuth 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	4 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
Balluff	Position transducer	CAN node
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%	
Back-up 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, thereby slowing the rotor speed.

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

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 over-speed and rotating errors.

The turbine is also equipped with a VOG (Vestas Overspeed Guard), an independent computer module that measures 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	17.3 (Rotor rpm) / 1597 (Generator rpm)

Table 4-2: Overspeed protection data.

4.4 EMC System

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

- Council Directive 2004/108/EC of 15 December 2004 on the approximation of the laws of the Member States relating to Electromagnetic Compatibility.
- The (Electromagnetic Compatibility) EMC-Directive with later amendments.

4.5 Lightning 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. 27).

4.6 Earthing (also Known as Grounding)

The Vestas Earthing System is based on foundation earthing.

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

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

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. 23 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 maximum intervals of 9 metres along the tower ladder between platforms.

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

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

Anchorage 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 block the rotor and drive train.

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

5.7 Lighting

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

There is emergency light 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). In operation mode ear protection is required.

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.

Above the generator there must be a fire blanket which can be used to put out small fires.

5.12 Warning Signs

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

5.13 Manuals and Warnings

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 Vestas Wind Systems A/S Environmental System certified according to ISO 14001:2004.

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

7 Approvals, Certificates and Design Codes

7.1 Type Approvals

The 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
*Refer to section 9.1 Climate and Site Conditions, p. 28 for details.		

Table 7-1: Type approvals.

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

Table 7-2: 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 to 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 7-3: 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 Co-ordination	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
Generator	IEC 60034
Specification for Sulphur Hexafluoride for Electrical Equipment	IEC 60376
Rotating Electrical Machines	IEC 34

Design Codes – Electrical Equipment	
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 7-4: 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 7-5: 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. 27.

Design Codes – EMC System	
Designed according to	IEC 61400-1: 2005
Further robustness requirements according to	TPS 901785

Table 7-6: 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 7-7: 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

8.1 Nacelle Colour and Surface Treatment

Surface Treatment of Vestas Nacelles	
Standard Nacelle Colours	RAL 7035 (light grey)
Gloss	According to ISO 2813

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% UV resistant	Maximum 50%

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%

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 (Normal Temperature Turbine)	-30° 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.

Average Design Parameters	
Wind Climate	**IEC S**
Wind Speed	7.5 m/s
A-factor	8.45 m/s
Form Factor, c	2.0
Turbulence Intensity according to IEC 61400-1, including Wind Farm Turbulence (@15 m/s – 90% quantile)	18%
Wind Shear	0.20
Inflow Angle (vertical)	8°

Table 9-2: Average design parameters.

9.1.1 Complex Terrain

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

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

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, e.g. 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
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.

9.3 Operational Envelope – Grid Connection *

Values refer to hub height and as 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}	60 Hz
Maximum Steady State Voltage Jump	±2%	
Maximum Frequency Gradient	±4 Hz/sec	
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 above 110% of nominal for 60 seconds	440 V	759 V
Voltage above 115% of nominal for 2 seconds	460 V	794 V
Voltage above 120% of nominal for 0.08 seconds	480 V	828 V
Voltage above 125% of nominal for 0.005 seconds	500 V	863 V
Voltage below 90% of nominal for 60 seconds	360 V	621 V
Voltage below 85% of nominal for 11 seconds	340 V	586 V
Frequency is above [Hz] for 0.2 seconds	63.6 Hz	
Frequency is below [Hz] for 0.2 seconds	56.4 Hz	

Table 9-5: Generator and converter disconnecting values.

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

9.4 Performance – Fault Ride Through

The turbine is equipped with a reinforced Vestas Converter System in order to gain better control of the generator during grid faults. The controllers and contactors have a UPS backup system in order 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 9-1, p. 31.

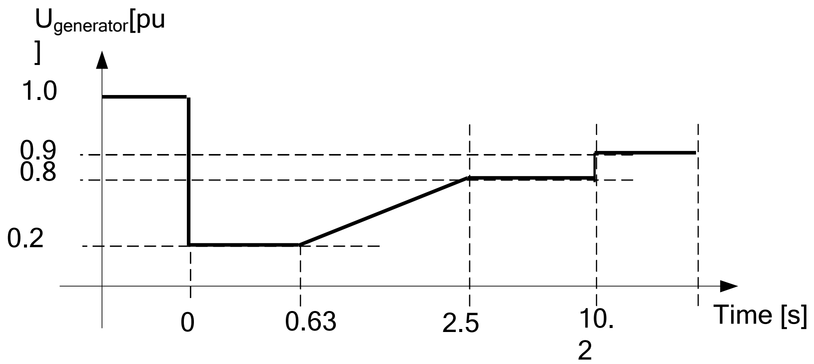


Figure 9-1: Low-voltage tolerance curve for symmetrical and asymmetrical faults.

For grid disturbances outside the protection curve in Figure 9-2, p. 31, the turbine will be disconnected from the grid.

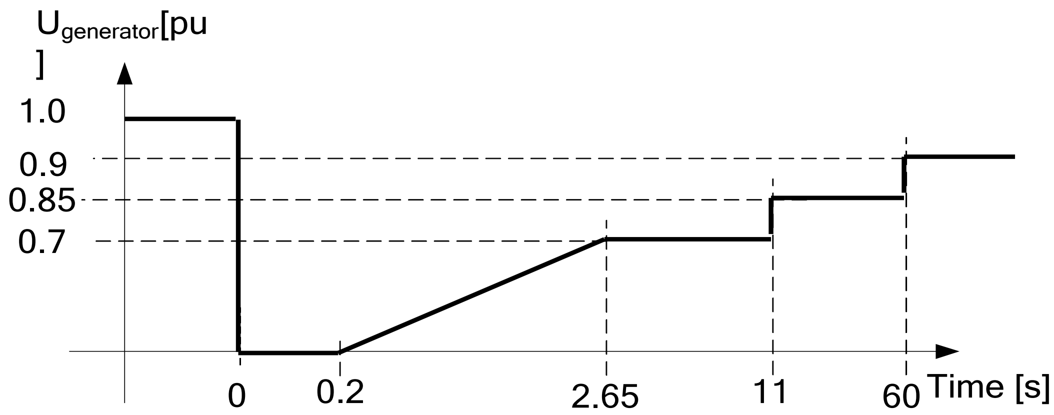


Figure 9-2: Default low-voltage protection settings for symmetrical and asymmetrical faults.

Power Recovery Time	
Power recovery to 90% of pre-fault level	Maximum1.0 second

Table 9-6: Power recovery time.

9.5 Current Contribution

During the grid dip, the generator is typically magnetized from the converter. The controller set points are set to keep the reactive current exchange with the grid close to zero and to keep as much torque on the generator as possible.

9.6 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.

9.7 Performance – Active Power Control

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

Maximum Ramp Rates for External Control	
Active Power	0.1 pu/sec

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

To protect the turbine active power cannot be controlled to values below the curve in Figure 9-3, p. 32.

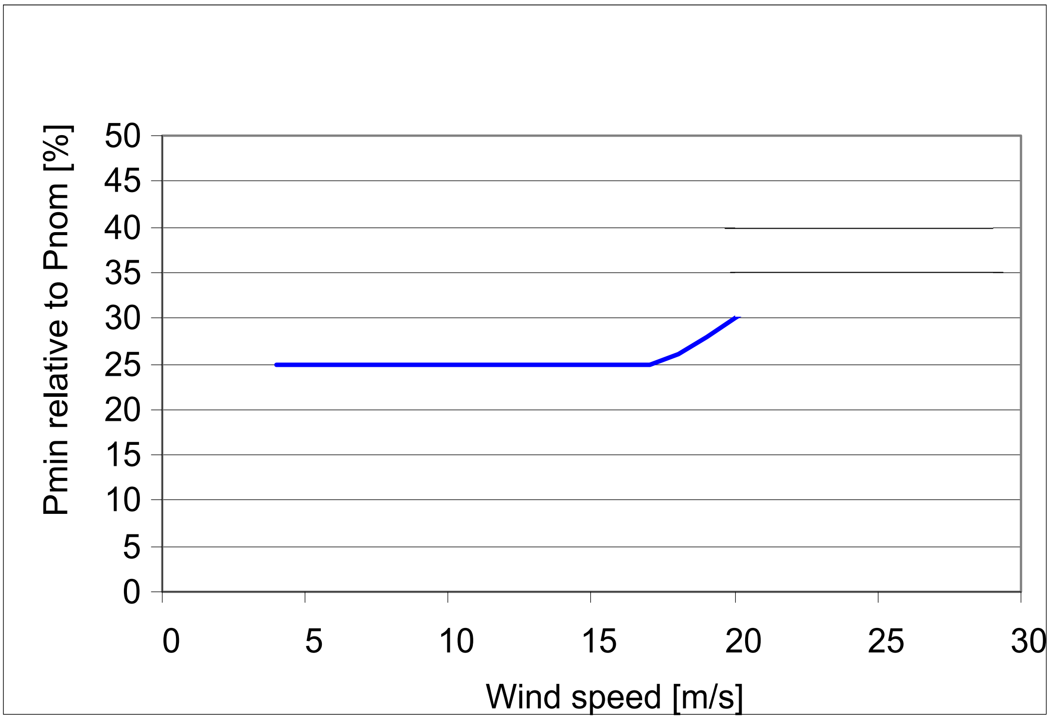


Figure 9-3: Minimum active power output dependent of wind speed.

9.8 Performance – Frequency Control

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

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

9.9 Performance – 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)
Oil Pump for Gearbox Lubrication	3.5 kW
HV Transformer located in the nacelle has a no-load loss of	3.9 kW @ grid voltage ≤ 33.0 kV 4.8 kW @ grid voltage ≥ 33.1 kV Standard IEC tolerances apply.

Table 9-8: Own consumption data.

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

See appendix section 12.1 Mode 0, p. 37, 12.2 Mode 1, p. 42 and 12.3 Mode 2, p. 47 for power curve, C_t values and noise level.

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	60 ± 0.5 Hz

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

10 Drawings

10.1 Structural Design – Illustration of Outer Dimensions

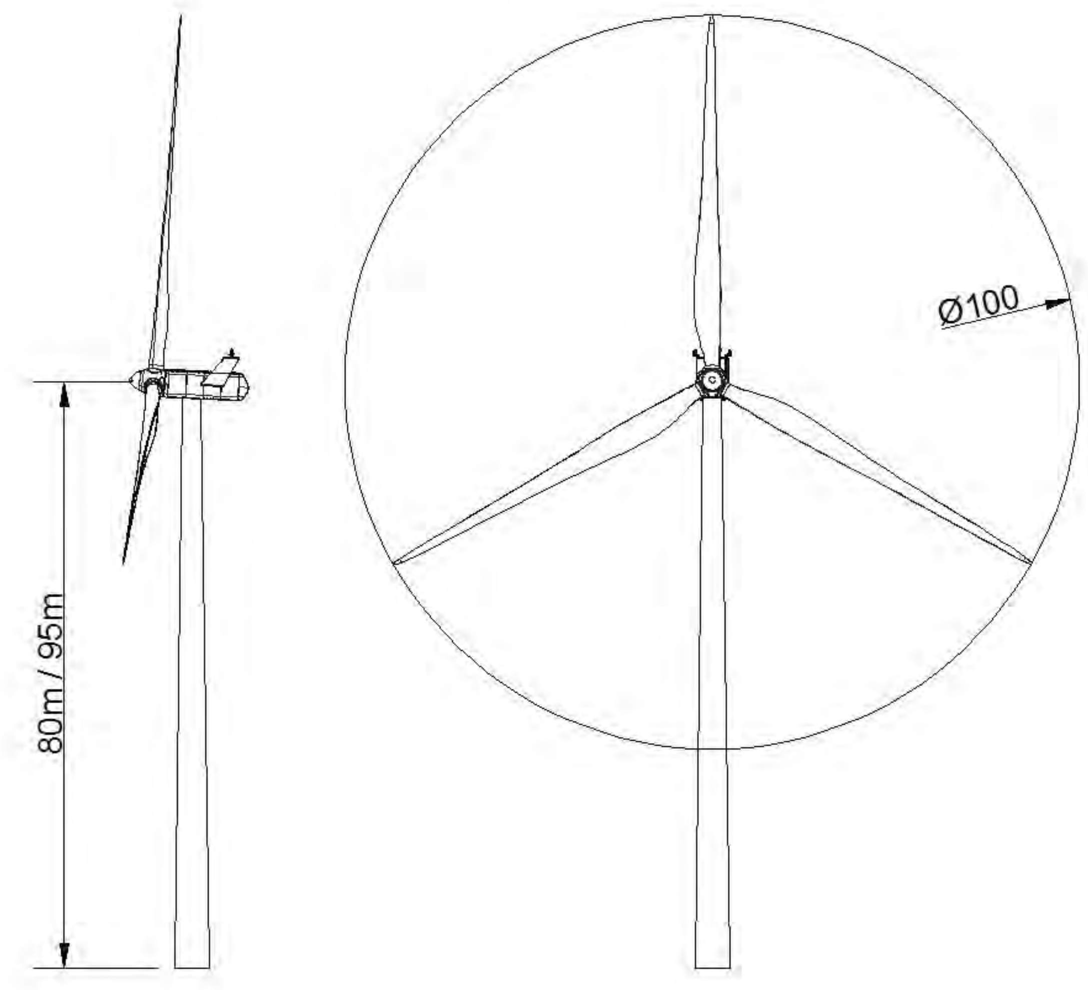


Figure 10-1: Illustration of outer dimensions: structure.

10.2 Structural Design – Side-View Drawing

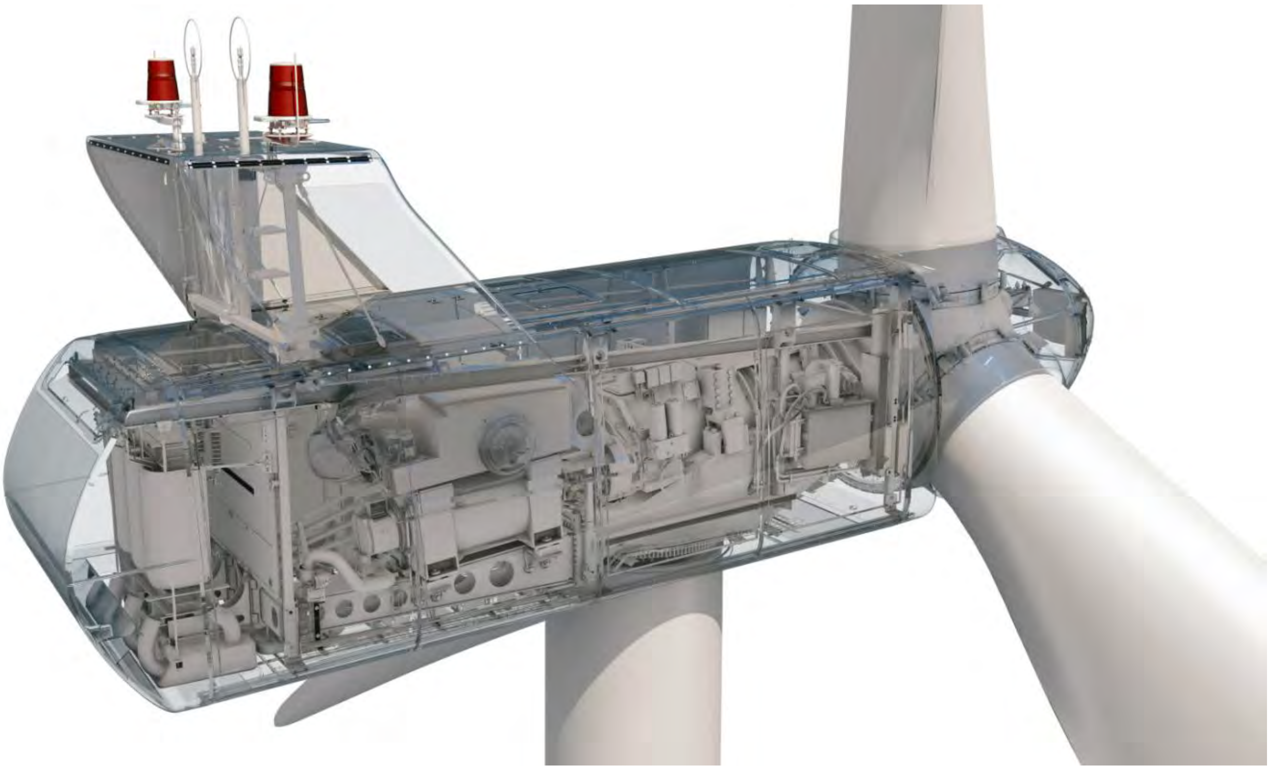


Figure 10-2: Side-view drawing.

11 General Reservations, Notes and Disclaimers

- These general specifications described in this document apply to the current version of the V100 wind turbine. Updated versions of the V100 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 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 little variation in frequency.
- A certain time allowance for turbine warm-up must be expected following grid dropout and/or periods of very low ambient temperature.
- The estimated power curve for the different estimated noise levels (sound power levels) is for wind speeds at 10 minute average value at hub height and perpendicular to the rotor plane.
- All listed start/stop parameters (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 curve, C_t values and sound power levels for noise mode 0 to 2 are defined below.

12.1 Mode 0

12.1.1 Power Curve, Noise Mode 0

Power Curve, Noise Mode 0														
	Air density kg/m³													
Wind speed [m/s]	**1.225**	**0.95**	**0.975**	**1.0**	**1.025**	**1.05**	**1.075**	**1.1**	**1.125**	**1.15**	**1.175**	**1.2**	**1.25**	**1.275**
3	**13**	9	9	9	10	10	11	11	11	12	12	13	14	15
3.5	**53**	34	36	38	39	41	43	45	46	48	50	52	55	57
4	**112**	80	83	86	89	92	95	98	101	104	106	109	115	118
4.5	**181**	136	140	144	148	152	156	160	165	169	173	177	185	189
5	**260**	198	203	209	215	220	226	232	237	243	248	254	265	271
5.5	**353**	270	278	285	293	300	308	315	323	330	338	345	360	368
6	**462**	356	365	375	385	395	404	414	424	433	443	453	472	481
6.5	**581**	443	455	468	481	493	506	518	531	544	556	569	594	606
7	**736**	563	579	595	611	626	642	658	673	689	705	720	751	767
7.5	**911**	700	720	739	758	777	796	816	835	854	873	892	930	949
8	**1108**	856	879	902	925	948	971	994	1017	1040	1063	1086	1131	1153
8.5	**1321**	1028	1055	1082	1110	1137	1163	1190	1216	1243	1269	1295	1347	1372
9	**1524**	1212	1243	1273	1304	1335	1363	1392	1421	1449	1474	1499	1547	1570
9.5	**1679**	1397	1429	1460	1491	1522	1547	1572	1597	1622	1641	1660	1695	1710
10	**1766**	1566	1591	1616	1641	1666	1682	1699	1716	1733	1744	1755	1773	1780
10.5	**1800**	1689	1705	1721	1737	1753	1762	1770	1779	1788	1792	1796	1802	1804
11	**1811**	1764	1772	1779	1786	1794	1797	1800	1803	1807	1808	1809	1812	1813
11.5	**1815**	1796	1799	1802	1805	1808	1809	1811	1812	1813	1814	1814	1815	1815
12	**1815**	1808	1810	1811	1812	1814	1814	1814	1815	1815	1815	1815	1815	1815
12.5	**1815**	1813	1814	1814	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815
13	**1815**	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815
13.5	**1815**	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815
14	**1815**	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815
14.5	**1815**	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815
15	**1815**	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815
15.5	**1815**	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815
16	**1815**	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815

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**
16.5	**1815**	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815
17	**1815**	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815
17.5	**1815**	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815
18	**1815**	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815
18.5	**1815**	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815
19	**1815**	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815
19.5	**1815**	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815
20	**1815**	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815

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

12.1.2 Ct Values, Noise Mode 0

Ct 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	**0.874**	0.874	0.874	0.874	0.874	0.874	0.874	0.874	0.874	0.874	0.874	0.874	0.874	0.874
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	**0.877**	0.877	0.877	0.877	0.877	0.877	0.877	0.877	0.877	0.877	0.877	0.877	0.877	0.877
4.5	**0.847**	0.847	0.847	0.847	0.847	0.847	0.847	0.847	0.847	0.847	0.847	0.847	0.847	0.847
5	**0.820**	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820	0.820
5.5	**0.806**	0.806	0.806	0.806	0.806	0.806	0.806	0.806	0.806	0.806	0.806	0.806	0.806	0.806
6	**0.802**	0.802	0.802	0.802	0.802	0.802	0.802	0.802	0.802	0.802	0.802	0.802	0.802	0.802
6.5	**0.814**	0.814	0.814	0.814	0.814	0.814	0.814	0.814	0.814	0.814	0.814	0.814	0.814	0.814
7	**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	0.807
7.5	**0.804**	0.804	0.804	0.804	0.804	0.804	0.804	0.804	0.804	0.804	0.804	0.804	0.804	0.804
8	**0.795**	0.800	0.800	0.799	0.799	0.799	0.799	0.798	0.798	0.797	0.796	0.796	0.794	0.793
8.5	**0.768**	0.786	0.784	0.783	0.782	0.780	0.779	0.777	0.776	0.774	0.772	0.770	0.766	0.764
9	**0.716**	0.756	0.754	0.751	0.749	0.746	0.743	0.739	0.736	0.732	0.727	0.721	0.710	0.704
9.5	**0.636**	0.713	0.708	0.703	0.698	0.693	0.685	0.678	0.670	0.663	0.654	0.645	0.627	0.617
10	**0.545**	0.657	0.648	0.639	0.630	0.621	0.610	0.599	0.589	0.578	0.567	0.556	0.535	0.524
10.5	**0.459**	0.587	0.576	0.564	0.552	0.540	0.528	0.517	0.505	0.493	0.482	0.471	0.449	0.439
11	**0.389**	0.514	0.501	0.488	0.475	0.462	0.451	0.440	0.428	0.417	0.408	0.398	0.380	0.372
11.5	**0.333**	0.442	0.430	0.418	0.406	0.395	0.385	0.376	0.366	0.357	0.349	0.341	0.325	0.318
12	**0.288**	0.381	0.370	0.360	0.350	0.340	0.332	0.324	0.316	0.308	0.301	0.294	0.282	0.276
12.5	**0.251**	0.330	0.322	0.313	0.305	0.296	0.289	0.282	0.275	0.269	0.263	0.257	0.246	0.241
13	**0.222**	0.289	0.282	0.275	0.267	0.260	0.254	0.248	0.242	0.236	0.231	0.227	0.217	0.213
13.5	**0.197**	0.256	0.249	0.243	0.237	0.230	0.225	0.220	0.215	0.210	0.206	0.201	0.193	0.189
14	**0.176**	0.227	0.222	0.216	0.211	0.205	0.201	0.196	0.192	0.187	0.184	0.180	0.173	0.169
14.5	**0.158**	0.203	0.199	0.194	0.189	0.184	0.180	0.176	0.172	0.168	0.165	0.161	0.155	0.152
15	**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
15.5	**0.129**	0.165	0.161	0.157	0.153	0.150	0.146	0.143	0.140	0.137	0.134	0.132	0.127	0.124
16	**0.117**	0.150	0.146	0.143	0.139	0.136	0.133	0.130	0.127	0.125	0.122	0.120	0.115	0.113
16.5	**0.107**	0.137	0.133	0.130	0.127	0.124	0.121	0.119	0.116	0.114	0.112	0.109	0.105	0.103
17	**0.098**	0.125	0.122	0.119	0.116	0.114	0.111	0.109	0.107	0.104	0.102	0.100	0.097	0.095
17.5	**0.091**	0.115	0.112	0.109	0.107	0.104	0.102	0.100	0.098	0.096	0.094	0.092	0.089	0.087
18	**0.084**	0.105	0.103	0.101	0.098	0.096	0.094	0.092	0.090	0.088	0.087	0.085	0.082	0.081
18.5	**0.077**	0.097	0.095	0.093	0.091	0.089	0.087	0.085	0.083	0.082	0.080	0.079	0.076	0.075
19	**0.072**	0.090	0.088	0.086	0.084	0.082	0.081	0.079	0.078	0.076	0.075	0.073	0.071	0.069

Ct 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**
19.5	**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
20	**0.062**	0.078	0.076	0.075	0.073	0.071	0.070	0.069	0.067	0.066	0.065	0.063	0.061	0.060

Table 12-2: Noise mode 0, Ct values.

12.1.3 Noise Curve, Noise Mode 0

Sound Power Level at Hub Height, Noise Mode 0		
Conditions for Sound Power Level:	**Measurement standard IEC 61400-11 ed. 2 2002** **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]	93.8 4.2	93.8 4.3
LwA @ 4 m/s (10 m above ground) [dBA] Wind speed at hub height [m/s]	96.0 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	100.7 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 12-3: Noise curve, noise mode 0.

12.2 Mode 1

12.2.1 Power Curve, Noise Mode 1

Power Curve, 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	**13**	9	9	9	10	10	11	11	11	12	12	13	14	15
3.5	**53**	34	36	38	39	41	43	45	46	48	50	52	55	57
4	**112**	80	83	86	89	92	95	98	101	104	106	109	115	118
4.5	**180**	134	139	143	147	151	155	159	163	167	171	175	184	188
5	**256**	195	200	206	211	217	223	228	234	239	245	250	261	267
5.5	**346**	265	273	280	287	295	302	310	317	324	332	339	354	361
6	**453**	349	358	368	377	387	396	406	415	425	434	444	463	472
6.5	**576**	439	451	464	476	489	501	514	526	539	551	564	588	601
7	**728**	558	573	589	604	620	635	651	666	682	697	713	744	759
7.5	**902**	693	712	731	750	769	788	807	826	845	864	883	920	939
8	**1098**	847	870	893	916	939	961	984	1007	1030	1053	1075	1120	1143
8.5	**1312**	1019	1046	1073	1100	1127	1154	1180	1207	1234	1260	1286	1338	1364
9	**1519**	1204	1234	1265	1296	1326	1355	1384	1413	1443	1468	1494	1542	1565
9.5	**1678**	1392	1423	1455	1486	1518	1543	1569	1594	1619	1639	1658	1693	1709
10	**1766**	1562	1588	1613	1638	1664	1681	1698	1715	1732	1743	1754	1773	1780
10.5	**1799**	1687	1703	1720	1736	1753	1761	1770	1779	1788	1791	1795	1801	1803
11	**1811**	1764	1772	1779	1787	1794	1798	1801	1804	1807	1808	1810	1812	1813
11.5	**1814**	1796	1799	1802	1805	1809	1810	1811	1812	1813	1813	1814	1815	1815
12	**1815**	1809	1810	1811	1812	1813	1814	1814	1814	1815	1815	1815	1815	1815
12.5	**1815**	1813	1814	1814	1814	1815	1815	1815	1815	1815	1815	1815	1815	1815
13	**1815**	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815
13.5	**1815**	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815
14	**1815**	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815
14.5	**1815**	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815
15	**1815**	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815
15.5	**1815**	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815
16	**1815**	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815
16.5	**1815**	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815
17	**1815**	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815
17.5	**1815**	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815
18	**1815**	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815

Power Curve, 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**
18.5	**1815**	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815
19	**1815**	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815
19.5	**1815**	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815
20	**1815**	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815

Table 12-4: Power curve, noise mode 1.

12.2.2 Ct Values, Noise Mode 1

Ct 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	**0.874**	0.874	0.874	0.874	0.874	0.874	0.874	0.874	0.874	0.874	0.874	0.874	0.874	0.874
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	**0.863**	0.863	0.863	0.863	0.863	0.863	0.863	0.863	0.863	0.863	0.863	0.863	0.863	0.863
4.5	**0.809**	0.809	0.809	0.809	0.809	0.809	0.809	0.809	0.809	0.809	0.809	0.809	0.809	0.809
5	**0.764**	0.764	0.764	0.764	0.764	0.764	0.764	0.764	0.764	0.764	0.764	0.764	0.764	0.764
5.5	**0.741**	0.741	0.741	0.741	0.741	0.741	0.741	0.741	0.741	0.741	0.741	0.741	0.741	0.741
6	**0.733**	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733	0.733
6.5	**0.766**	0.766	0.766	0.766	0.766	0.766	0.766	0.766	0.766	0.766	0.766	0.766	0.766	0.766
7	**0.755**	0.755	0.755	0.755	0.755	0.755	0.755	0.755	0.755	0.755	0.755	0.755	0.755	0.755
7.5	**0.750**	0.749	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750	0.750
8	**0.748**	0.749	0.749	0.749	0.749	0.749	0.749	0.749	0.749	0.749	0.748	0.748	0.748	0.747
8.5	**0.735**	0.745	0.744	0.744	0.743	0.742	0.741	0.741	0.740	0.739	0.738	0.737	0.734	0.733
9	**0.699**	0.729	0.727	0.726	0.724	0.722	0.720	0.717	0.715	0.712	0.708	0.703	0.694	0.689
9.5	**0.631**	0.699	0.695	0.691	0.687	0.683	0.676	0.669	0.663	0.656	0.648	0.639	0.622	0.613
10	**0.544**	0.652	0.643	0.634	0.626	0.617	0.607	0.597	0.586	0.576	0.565	0.555	0.533	0.522
10.5	**0.458**	0.585	0.574	0.562	0.551	0.539	0.527	0.516	0.504	0.492	0.481	0.470	0.448	0.438
11	**0.388**	0.514	0.501	0.488	0.475	0.462	0.451	0.440	0.428	0.417	0.408	0.398	0.380	0.371
11.5	**0.333**	0.442	0.430	0.418	0.406	0.395	0.385	0.376	0.366	0.356	0.349	0.341	0.325	0.318
12	**0.288**	0.381	0.370	0.360	0.350	0.340	0.332	0.324	0.316	0.308	0.301	0.294	0.282	0.276
12.5	**0.251**	0.331	0.322	0.313	0.305	0.296	0.289	0.282	0.275	0.269	0.263	0.257	0.246	0.241
13	**0.222**	0.289	0.282	0.275	0.267	0.260	0.254	0.248	0.242	0.236	0.231	0.227	0.217	0.213
13.5	**0.197**	0.256	0.249	0.243	0.237	0.230	0.225	0.220	0.215	0.210	0.206	0.201	0.193	0.189
14	**0.176**	0.227	0.222	0.216	0.211	0.205	0.201	0.196	0.192	0.187	0.184	0.180	0.173	0.169
14.5	**0.158**	0.203	0.199	0.194	0.189	0.184	0.180	0.176	0.172	0.168	0.165	0.161	0.155	0.152
15	**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
15.5	**0.129**	0.165	0.161	0.157	0.153	0.150	0.146	0.143	0.140	0.137	0.134	0.132	0.127	0.124
16	**0.117**	0.150	0.146	0.143	0.139	0.136	0.133	0.130	0.127	0.125	0.122	0.120	0.115	0.113
16.5	**0.107**	0.137	0.133	0.130	0.127	0.124	0.121	0.119	0.116	0.114	0.112	0.109	0.105	0.103
17	**0.098**	0.125	0.122	0.119	0.116	0.114	0.111	0.109	0.107	0.104	0.102	0.100	0.097	0.095
17.5	**0.091**	0.115	0.112	0.109	0.107	0.104	0.102	0.100	0.098	0.096	0.094	0.092	0.089	0.087
18	**0.084**	0.105	0.103	0.101	0.098	0.096	0.094	0.092	0.090	0.088	0.087	0.085	0.082	0.081
18.5	**0.077**	0.097	0.095	0.093	0.091	0.089	0.087	0.085	0.083	0.082	0.080	0.079	0.076	0.075
19	**0.072**	0.090	0.088	0.086	0.084	0.082	0.081	0.079	0.078	0.076	0.075	0.073	0.071	0.069

Ct 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**
19.5	**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
20	**0.062**	0.078	0.076	0.075	0.073	0.071	0.070	0.069	0.067	0.066	0.065	0.063	0.061	0.060

Table 12-5: Ct values, noise mode 1.

12.2.3 Noise Curve, Noise Mode 1

Sound Power Level at Hub Noise Height, Mode 1		
Conditions for Sound Power Level	**Measurement standard IEC 61400-11 ed. 2 2002.** **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]	93.7 4.2	93.7 4.3
LwA @ 4 m/s (10 m above ground) [dBA] Wind speed at hub height [m/s]	95.3 5.6	95.7 5.7
LwA @ 5 m/s (10 m above ground) [dBA] Wind speed at hub height [m/s]	99.1 7.0	99.7 7.2
LwA @ 6 m/s (10 m above ground) [dBA] Wind speed at hub height [m/s]	102.9 8.4	103.4 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 12-6: Noise curve, noise mode 1.

12.3 Mode 2

12.3.1 Power Curve, Noise Mode 2

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	9	10	10	11	11	11	12	12	13	14	15
3.5	**53**	34	36	38	39	41	43	45	46	48	50	52	55	57
4	**112**	80	83	86	89	92	95	98	101	104	106	109	115	118
4.5	**181**	136	140	144	148	152	156	160	165	169	173	177	185	189
5	**260**	198	203	209	215	220	226	231	237	243	248	254	265	271
5.5	**353**	270	278	285	293	300	308	315	323	330	338	345	360	367
6	**462**	355	365	375	384	394	404	413	423	433	442	452	471	481
6.5	**581**	443	455	468	480	493	506	518	531	543	556	568	594	606
7	**735**	563	579	594	610	626	642	657	673	688	704	720	751	766
7.5	**908**	697	717	736	755	774	793	812	831	851	870	889	926	945
8	**1090**	840	863	886	909	932	954	977	999	1022	1045	1067	1113	1135
8.5	**1271**	981	1008	1034	1061	1087	1113	1140	1166	1192	1218	1244	1297	1323
9	**1437**	1112	1142	1172	1201	1231	1261	1290	1320	1349	1379	1408	1465	1494
9.5	**1580**	1227	1260	1293	1325	1358	1390	1423	1455	1487	1518	1549	1607	1634
10	**1689**	1331	1367	1402	1437	1473	1506	1540	1573	1607	1634	1661	1709	1729
10.5	**1757**	1425	1462	1499	1536	1573	1604	1635	1666	1697	1717	1737	1768	1780
11	**1792**	1512	1549	1585	1622	1659	1683	1708	1732	1757	1768	1780	1797	1802
11.5	**1805**	1592	1624	1657	1690	1722	1738	1755	1771	1787	1793	1799	1808	1811
12	**1811**	1666	1691	1715	1740	1764	1774	1783	1792	1802	1805	1808	1812	1813
12.5	**1813**	1726	1742	1757	1773	1789	1794	1799	1804	1809	1810	1812	1814	1814
13	**1814**	1765	1774	1784	1793	1802	1805	1807	1810	1812	1813	1814	1815	1815
13.5	**1815**	1786	1791	1797	1803	1808	1810	1811	1813	1814	1815	1815	1815	1815
14	**1815**	1802	1805	1808	1811	1813	1814	1814	1814	1815	1815	1815	1815	1815
14.5	**1815**	1812	1812	1813	1814	1815	1815	1815	1815	1815	1815	1815	1815	1815
15	**1815**	1813	1813	1814	1814	1815	1815	1815	1815	1815	1815	1815	1815	1815
15.5	**1815**	1814	1814	1814	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815
16	**1815**	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815
16.5	**1815**	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815
17	**1815**	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815
17.5	**1815**	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815
18	**1815**	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815

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**
18.5	**1815**	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815
19	**1815**	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815
19.5	**1815**	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815
20	**1815**	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815

Table 12-7: Power curve, noise mode 2.

12.3.2 Ct Values, Noise Mode 2

Ct 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	**0.874**	0.874	0.874	0.874	0.874	0.874	0.874	0.874	0.874	0.874	0.874	0.874	0.874	0.874
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	**0.877**	0.877	0.877	0.877	0.877	0.877	0.877	0.877	0.877	0.877	0.877	0.877	0.877	0.877
4.5	**0.847**	0.847	0.847	0.847	0.847	0.846	0.847	0.847	0.847	0.847	0.847	0.847	0.847	0.847
5	**0.818**	0.818	0.818	0.818	0.818	0.817	0.818	0.818	0.818	0.818	0.818	0.818	0.818	0.818
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**	0.796	0.796	0.796	0.796	0.796	0.796	0.796	0.796	0.796	0.796	0.796	0.796	0.796
6.5	**0.811**	0.811	0.811	0.811	0.811	0.811	0.811	0.811	0.811	0.811	0.811	0.811	0.811	0.811
7	**0.800**	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800	0.800
7.5	**0.783**	0.783	0.783	0.783	0.783	0.782	0.783	0.783	0.783	0.783	0.783	0.783	0.783	0.783
8	**0.747**	0.747	0.747	0.747	0.747	0.747	0.747	0.747	0.747	0.747	0.747	0.747	0.747	0.747
8.5	**0.695**	0.695	0.695	0.695	0.695	0.695	0.695	0.695	0.695	0.695	0.695	0.695	0.695	0.695
9	**0.634**	0.634	0.634	0.634	0.634	0.634	0.634	0.634	0.634	0.634	0.634	0.634	0.634	0.634
9.5	**0.569**	0.570	0.570	0.570	0.570	0.570	0.570	0.570	0.570	0.570	0.570	0.569	0.567	0.565
10	**0.505**	0.513	0.513	0.513	0.513	0.513	0.513	0.513	0.512	0.512	0.509	0.507	0.500	0.496
10.5	**0.441**	0.462	0.462	0.462	0.462	0.462	0.460	0.458	0.456	0.454	0.450	0.445	0.435	0.428
11	**0.381**	0.417	0.416	0.415	0.415	0.414	0.410	0.407	0.403	0.400	0.394	0.388	0.375	0.368
11.5	**0.330**	0.377	0.375	0.373	0.371	0.369	0.364	0.359	0.354	0.349	0.342	0.336	0.323	0.317
12	**0.287**	0.342	0.339	0.335	0.331	0.328	0.322	0.316	0.311	0.305	0.299	0.293	0.281	0.275
12.5	**0.251**	0.310	0.305	0.300	0.295	0.290	0.285	0.279	0.273	0.267	0.262	0.257	0.246	0.241
13	**0.222**	0.279	0.274	0.268	0.263	0.258	0.252	0.247	0.241	0.236	0.231	0.226	0.217	0.213
13.5	**0.197**	0.250	0.245	0.240	0.235	0.229	0.224	0.220	0.215	0.210	0.206	0.201	0.193	0.189
14	**0.176**	0.225	0.220	0.215	0.210	0.205	0.201	0.196	0.192	0.187	0.184	0.180	0.173	0.169
14.5	**0.158**	0.203	0.198	0.193	0.189	0.184	0.180	0.176	0.172	0.168	0.165	0.161	0.155	0.152
15	**0.142**	0.182	0.178	0.174	0.169	0.165	0.162	0.158	0.155	0.151	0.148	0.145	0.140	0.137
15.5	**0.129**	0.165	0.161	0.157	0.153	0.150	0.146	0.143	0.140	0.137	0.134	0.132	0.127	0.124
16	**0.117**	0.150	0.146	0.143	0.139	0.136	0.133	0.130	0.127	0.125	0.122	0.120	0.115	0.113
16.5	**0.107**	0.137	0.133	0.130	0.127	0.124	0.121	0.119	0.116	0.114	0.112	0.109	0.105	0.103
17	**0.098**	0.125	0.122	0.119	0.116	0.114	0.111	0.109	0.107	0.104	0.102	0.100	0.097	0.095
17.5	**0.091**	0.115	0.112	0.109	0.107	0.104	0.102	0.100	0.098	0.096	0.094	0.092	0.089	0.087
18	**0.084**	0.105	0.103	0.101	0.098	0.096	0.094	0.092	0.090	0.088	0.087	0.085	0.082	0.081
18.5	**0.077**	0.097	0.095	0.093	0.091	0.089	0.087	0.085	0.083	0.082	0.080	0.079	0.076	0.075
19	**0.072**	0.090	0.088	0.086	0.084	0.082	0.081	0.079	0.078	0.076	0.075	0.073	0.071	0.069

Ct 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**
19.5	**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
20	**0.062**	0.078	0.076	0.075	0.073	0.071	0.070	0.069	0.067	0.066	0.065	0.063	0.061	0.060

Table 12-8: Ct values, noise mode 2..

12.3.3 Noise Curve, Noise Mode 2

Sound Power Level at Hub Height, Noise Mode 2		
Conditions for Sound Power Level	**Measurement standard IEC 61400-11 ed. 2 2002** **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]	93.8 4.2	93.8 4.3
LwA @ 4 m/s (10 m above ground) [dBA] Wind speed at hub height [m/s]	96.0 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	100.7 7.2
LwA @ 6 m/s (10 m above ground) [dBA] Wind speed at hub height [m/s]	103.0 8.4	103.0 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: Noise curve, noise mode 2.