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MOONIES HILL ENERGY

FLAT ROCKS WIND FARM

KOJONUP

NOISE IMPACT ASSESSMENT

JULY 2011

OUR REFERENCE:13231-4-10226-02

DOCUMENT CONTROL PAGE

NOISE IMPACT ASSESSMENT
KOJONUP

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FOR

MOONIES HILL ENERGY

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1. INTRODUCTION

Herring Storer acoustics were commissioned to carry out a noise impact assessment for the proposed Flat Rocks Wind Farm development.

The proposed development site is located to the east of Albany Highway, approximately 260km southeast of Perth and 27km southwest of the township of Katanning in southwest Western Australia.

The proposed wind farm consists of 74 wind turbines, in cleared wheat farming country.

See Appendix A for locations of turbines and noise sensitive premises.

The noise impact assessment has been carried out in accordance with the EPA of South Australia *"Wind Farms – Environmental noise guidelines (interim) – December 2007"* (Guidelines) which is the guidelines recognised by the Department of Environment and Conservation for the assessment of wind farms.

2. SUMMARY

Noise levels were assessed at 34 identified receiver points, with these locations shown in Appendix A.

Noise emissions at "non-stake holders" have been calculated to comply with the background noise criteria under all wind conditions.

Noise levels at "stake holders" SH27 and SH28 have been calculated to marginally exceed the background noise criteria for 8m/s at hub height (80m).

3. CRITERIA

According to the Western Australian Planning bulletin number 67 "Guidelines for Wind Farm Development" – May 2004, the noise impact of proposed wind farms in Western Australia should be assessed in accordance with the criteria and approach of assessing wind farms described in the EPA of South Australia *"Wind Farms – Environmental noise guidelines (interim) – December 2007"* (Guidelines).

The Guidelines recommend the following criteria for the assessment of noise levels associated with proposed wind farms;

The predicted equivalent noise level ($L_{Aeq,10\ minutes}$), adjusted for tonality in accordance with the Guidelines, should not exceed :

- 35 dB(A), or
- 40 dB(A) in a primary production / rural industry zone, or
- the "Alternative Minimum Criteria" (Varying With Wind Speed); or
- the background noise ($L_{A90,10\ minutes}$) by more than 5 dB(A).

The criteria for background noise levels will vary with wind speed, as will wind turbine generated noise.

The alternative minimum criterion, varying with wind speed, is listed below in Table 3.1. This conservative minimum criterion has been determined based on a comparison of background noise levels at a number of existing and proposed wind farm sites around Australia.

Table 3.1 – Alternative Minimum Criteria (Varying With Wind Speed)

	Wind Speed at 10m above ground level					
	≤ 5	**6**	**7**	**8**	**9**	**≥ 10**
Minimum Criteria L_{Aeq} [dB(A)]	35	37	38	40	41	43

Based on the results of background noise monitoring undertaken during November 2010 – February 2011 (presented in Herring Storer Report ref: 12777-4-10226-01), the criteria for wind turbine noise are as presented in Table 3.2. See Appendix D for background noise monitoring locations.

Table 3.2 – Noise Criteria Based on Background Noise Levels, dB(A)

Background Monitoring Location	ID #	WIND SPEED AT 80m ABOVE GROUND LEVEL (m/s)						
		3	**4**	**5**	**6**	**7**	**8**	**9**
1	NSH12	41	40	39	39	39	39	40
2	NSH13	35	35	35	35	36	37	39
3	SH28	38	39	40	41	41	42	42
4	SH29	39	39	40	41	42	43	44
5	NSH09	35	35	35	36	38	40	42
6	SH27	35	35	35	35	35	37	38
7	NSH19	35	35	35	35	36	37	38
8	NSH06	35	35	36	37	39	41	42
9	NSH14	35	35	36	37	39	41	43
10	NSH15	39	39	39	39	40	41	42
11	SH30	38	38	38	37	38	38	39

This assessment has been based on the noise criteria based on monitored background noise levels. It is noted that the Guidelines have been developed to minimise the impact on the amenity of premises that do not have an agreement with wind farm developers. Our assessment includes all identified residential premises in the surrounding area, some of which may have such an agreement.

The applicable noise criteria for each identified location have been based on the closest background noise monitoring location. Due to poor correlation of data for background monitoring location 3 (SH28), the criteria for background monitoring location 6 (SH27) has been used in its place.

Participation in the development (or otherwise) is denoted in the ID of the residential premise, with “NSH” denoting “Non-Stake Holder” and “SH” denoting “Stake-Holder”.

4. MODELLING

Noise immissions at residential premises, due to the proposed wind farm, were determined by noise modelling, using the computer program “SoundPlan” version 7.0.

SoundPlan uses the theoretical sound power levels determined from measured sound pressure levels to calculate the noise level at any location.

The following input data was used in the SoundPlan model:

a) Topographical Information – Ground contours of the development area

b) Residential and Wind Turbine Locations – See Appendix A

c) Sound Power Levels, varying with wind speed, of the wind turbines intended to be utilised (Vestas V100-1.8 MW, 80m hub height) – See Appendix B

The Guidelines indicate that noise immissions should be modelled to reflect typical, (but not extreme) “worst case” meteorological conditions for sound propagation towards the receiver.

After a review of the literature available on the subject, noise level emissions were modelled using the ISO 9613-2:1996 algorithm, with the conditions listed in Table 4.1. These conditions, and calculating noise levels utilising a “G=0” ground absorption have been found to provide a generally realistic and conservative assessment of noise levels associated with wind turbines.

Table 4.1 – Meteorological Conditions

Condition	Value
Temperature	15 ^{o}C
Relative humidity	70%
Atmospheric Pressure	101.325 kPa

Noise levels attributable to the proposed wind farm were calculated for integer wind speeds 4 – 9m/s at a height of 80m (hub height). The sound power level of the turbines were varied for each integer wind speed, however the weather conditions within the model remained constant at the conditions stipulated in Table 4.1 above.

5. RESULTS

Noise contour plots are attached in Appendix C.

The predicted noise level at each identified residential premises are listed in Table 5.1 below for each of the hub height wind speeds considered.

Table 5.1 – Predicted Noise Levels at Identified Receiver Locations – Noise Mode 0

ID#	Predicted Noise Level, L_{Aeq} [dB(A)]					
	4m/s	5m/s	6m/s	7m/s	8m/s	9m/s
NSH01	14	17	17	20	20	20
NSH02	16	18	18	22	27	27
NSH03	25	27	27	31	36	36
NSH04	26	28	28	32	36	36
NSH05	15	17	17	21	24	24
NSH06	22	25	25	28	31	31
NSH07	18	20	20	24	29	29
NSH08	23	25	25	29	33	32
NSH09	25	27	27	31	35	35
NSH10	4	6	6	10	16	16
NSH11	11	13	13	17	24	24
NSH12	25	27	27	31	37	36
NSH13	24	26	26	30	36	36
NSH14	25	27	27	31	37	37
NSH15	26	28	28	32	37	37
NSH16	15	17	17	21	26	26
NSH17	14	16	16	20	23	23
NSH18	14	16	16	20	24	23
NSH19	24	26	26	30	35	35
NSH20	16	18	18	22	28	28
NSH21	7	9	9	13	22	21
NSH22	24	26	26	30	34	34
NSH23	16	18	18	22	22	22
NSH24	23	26	26	30	34	34
NSH25	6	8	8	12	20	20
Proposed NSH34	26	28	28	32	37	37
SH26	7	9	9	13	21	21
SH27	26	28	28	32	38	38
SH28	26	28	28	32	38	37
SH29	29	31	31	35	40	40
SH30	27	29	29	33	38	38
SH31	26	28	28	32	37	37
SH32	26	28	28	32	37	37
SH33	6	8	8	12	13	12

6. ASSESSMENT

Table 6.1 below summarises the level of exceedance to the noise criteria based on background noise monitoring, with the predicted levels exceeding the criteria highlighted in red and the level of exceedance listed in brackets adjacent.

Table 6.1 – Assessment of Noise Levels at Identified Receiver Locations – Noise Mode 0

ID#	Predicted Noise Level, L_{Aeq} [dB(A)]						Noise Criteria Based on Background Noise Level, L_{Aeq} [dB(A)]					
	4m/s	5m/s	6m/s	7m/s	8m/s	9m/s	4m/s	5m/s	6m/s	7m/s	8m/s	9m/s
NSH01	14	17	17	20	20	20	35	35	35	35	37	38
NSH02	16	18	18	22	27	27	35	35	35	35	37	38
NSH03	25	27	27	31	36	36	35	35	35	35	37	38
NSH04	26	28	28	32	36	36	39	40	41	42	43	44
NSH05	15	17	17	21	24	24	35	36	37	39	41	42
NSH06	22	25	25	28	31	31	35	36	37	39	41	42
NSH07	18	20	20	24	29	29	35	36	37	39	41	42
NSH08	23	25	25	29	33	32	35	35	36	38	40	42
NSH09	25	27	27	31	35	35	35	35	36	38	40	42
NSH10	4	6	6	10	16	16	40	39	39	39	39	40
NSH11	11	13	13	17	24	24	40	39	39	39	39	40
NSH12	25	27	27	31	37	36	40	39	39	39	39	40
NSH13	24	26	26	30	36	36	35	35	35	36	37	39
NSH14	25	27	27	31	37	37	35	36	37	39	41	43
NSH15	26	28	28	32	37	37	39	39	39	40	41	42
NSH16	15	17	17	21	26	26	35	35	35	36	37	39
NSH17	14	16	16	20	23	23	35	35	35	36	37	39
NSH18	14	16	16	20	24	23	35	35	35	36	37	38
NSH19	24	26	26	30	35	35	35	35	35	36	37	38
NSH20	16	18	18	22	28	28	35	35	36	38	40	42
NSH21	7	9	9	13	22	21	40	39	39	39	39	40
NSH22	24	26	26	30	34	34	40	39	39	39	39	40
NSH23	16	18	18	22	22	22	35	35	35	36	37	39
NSH24	23	26	26	30	34	34	40	39	39	39	39	40
NSH25	6	8	8	12	20	20	35	36	37	39	41	42
Proposed NSH34	26	28	28	32	37	37	35	35	35	35	37	38
SH26	7	9	9	13	21	21	35	35	35	35	37	38
SH27	26	28	28	32	38 (1)	38	35	35	35	35	37	38
SH28	26	28	28	32	38 (1)	37	35	35	35	35	37	38
SH29	29	31	31	35	40	40	39	40	41	42	43	44
SH30	27	29	29	33	38	38	38	38	37	38	38	39
SH31	26	28	28	32	37	37	35	35	35	36	37	38
SH32	26	28	28	32	37	37	35	35	35	36	37	38
SH33	6	8	8	12	13	12	35	35	35	35	37	38

As can be seen from the above tables, calculated noise levels at “non-stake holders” have been calculated to comply with the relevant background noise criteria, with marginal exceedances calculated at “stake-holder” locations.

7. CONCLUSION

Noise emissions at "non-stake holders" have been calculated to comply with the background noise criteria under all wind conditions.

Noise levels at "stake holders" SH27 and SH28 have been calculated to marginally exceed the background noise criteria for 8m/s at hub height (80m).

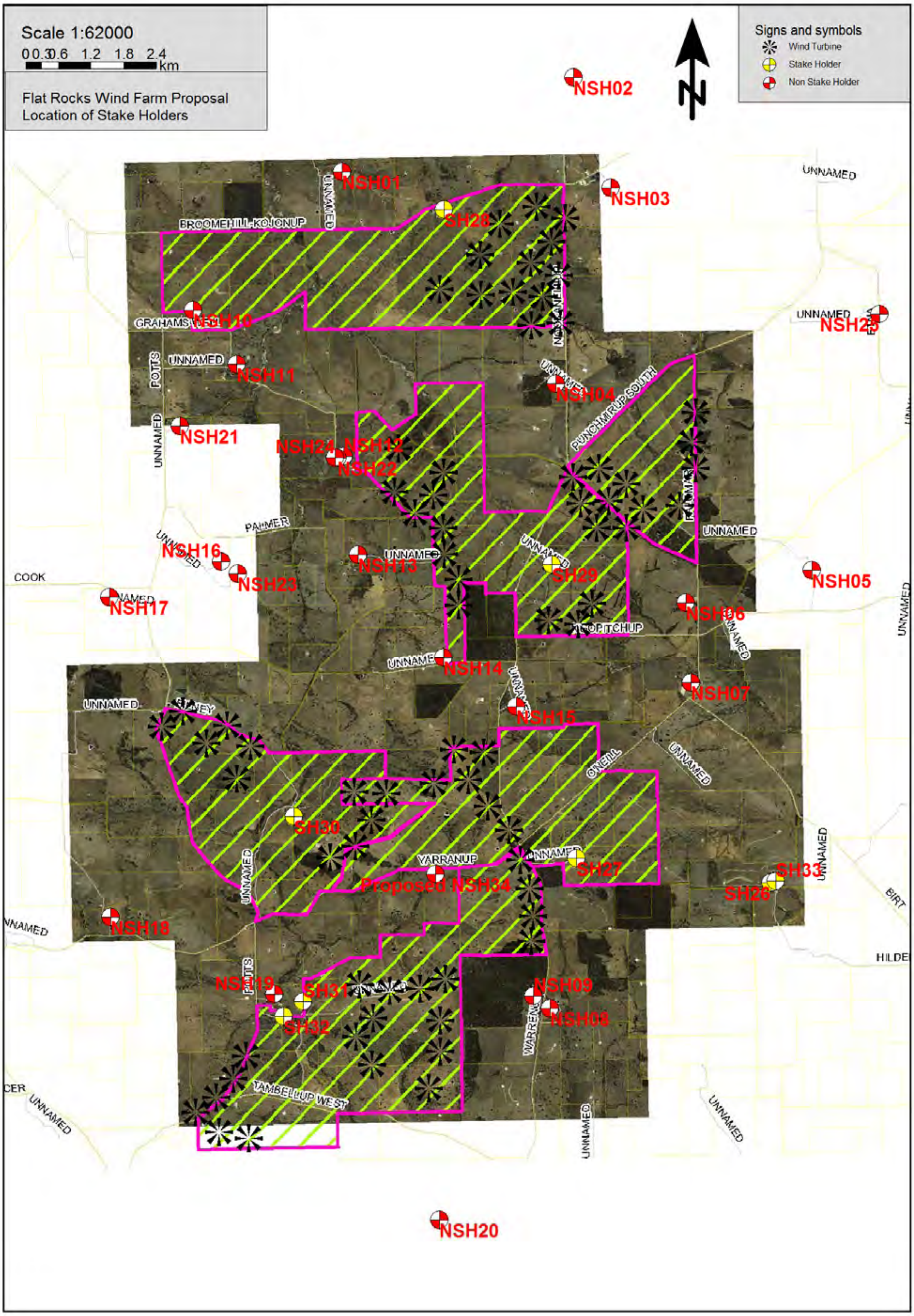
I trust the above meets your requirements on this matter. Should you have any further queries, do not hesitate to contact the undersigned.

Yours faithfully,
For **HERRING STORER ACOUSTICS**

George Watts

APPENDIX A

RESIDENTIAL AND WIND TURBINE LOCATIONS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0 0.3 0.6 1.2 1.8 2.4
km
Flat Rocks Wind Farm Proposal
Location of Stake Holders
Signs and symbols
Wind Turbine
Stake Holder
Non Stake Holder
NSH01
NSH02
NSH03
NSH04
NSH05
NSH06
NSH07
NSH08
NSH09
NSH10
NSH11
NSH12
NSH13
NSH14
NSH15
NSH16
NSH17
NSH18
NSH19
NSH20
NSH21
NSH22
NSH23
NSH24
SH26
SH27
SH28
SH29
SH30
SH31
SH32
SH33
Proposed NSH34
BROOMEHILL-KOJONUP
GRAHAMS
POTTS
PALMER
COOK
PUNCHMIRUP SOUTH
YARRANUP
YAMBELLUP WEST
WARREN
UNNAMED

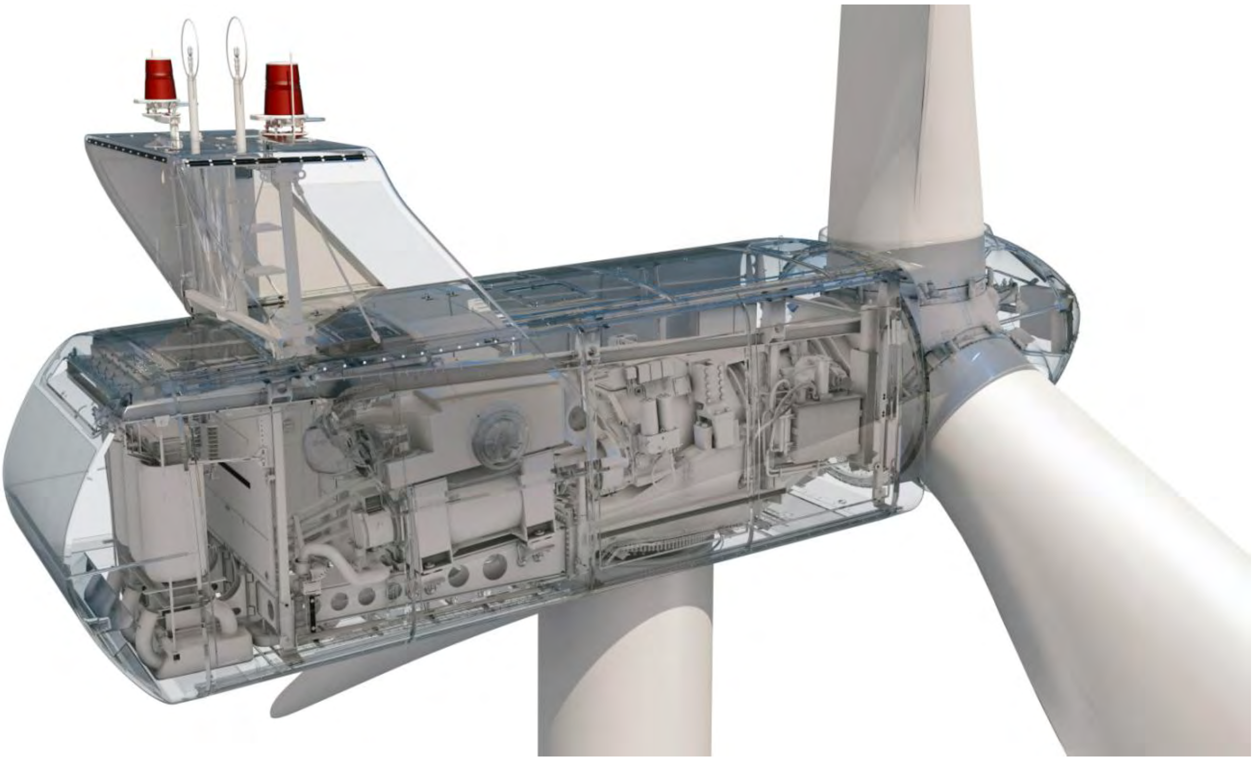
APPENDIX B

TURBINE SPECIFICATIONS

Class 1
Document no.: 0004-0153 V09
2010-10-06

General Specification

V100–1.8 MW 50 Hz VCS



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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. 39 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 utilizes a microprocessor pitch control system called OptiTip® and the 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 MW turbine is equipped with a 100-meter 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
Chord	3.9 m
Blade Root Outer Diameter	1.88 m

PP Blades	
PCD of Steel Root Inserts	1.80 m
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 4-point contact ball bearings.

Blade Bearing	
Type	2-row 4-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 4-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	Ø125/80 – 760
Number	1 pcs./ blade
Range	-5º to 90º

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 / 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 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	1:113 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 cm^3.

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 fibre glass tube. The coupling is fitted to 3-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 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˚/sec.

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

Tower Structure	
Type Description	Conical tubular
Hub Heights (HH)	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, 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
Base Frame Front	Cast EN-GJS-400-18U-LT / EN 1560
Base Frame Rear	Welded grid structure

Table 2-16: Nacelle base frame 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 Low Temperature (LT) turbine)
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/coolers but are considered as 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 3-way thermostatic valve, which 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 mechanical-driven oil pump and a plate heat exchanger, and the second circuit is equipped with an electrical-driven oil pump and a plate heat exchanger. The water circuit of the two plate heat exchangers are 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
No. 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
No. 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
No. 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 which 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: 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/min (50% glycol)
Water inlet pressure	Max 2.0 bar
Water inlet temperature	Maximum 54ºC
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. The cooler removes the internal losses in the generator and in three fans (two internal and one external). 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:

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 (generated by mechanical and electrical equipment) from the nacelle.

Nacelle Cooling	
Nominal air flow	1.2 m^3/s
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 3-phase asynchronous generator with wound rotor, which 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 exhausts it out through the rear end 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.

Generator	
Type Description	Asynchronous with wound rotor, slip rings and VCS
Rated Power (PN)	1.8 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)	0.90 ind – 0.95 cap
Over Speed Limit acc. to IEC (2 min.)	2900 rpm
Vibration Level	≤ 1.8 mm/s
Weight	Approximately 7500 kg
Generator Bearing - Temperature	2 PT100 sensors
Generator Stator Windings - Temperature	3 PT100 sensors placed at hot spots and 3 as back-up

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 4-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	3x70/70 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 a TN-system, which means the star point is connected to earth.

Transformer	
Type Description	Dry-type cast resin
Primary Voltage	6-35 kV
Rated Apparent 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	50/60 Hz
HV-tappings	± 2 x 2.5% offload
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 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 & 480V)	232 A
Rated Rotor Current (@ rated slip & 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
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 optical-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	3 channel PT100 module	CAN I/O module
CT6050	Blade controller	CAN node
Balluf	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 back up time for the UPS system is proportional to the power consumption. Actual back-up 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 V AC	
Rated Output Voltage	230 V AC	
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 back-up 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 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} **(415V 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), which is an independent computer module measuring the rotor RPM, and 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 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. Lightning strikes are considered force majeure, i.e. damage caused by lightning strikes is not warranted by Vestas.

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 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. 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 equipped 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 anchorage points in the tower, nacelle, 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. 29 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
Bedframe	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 7-1: 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 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 7-2: 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 1kV	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

Design Codes – Electrical Equipment	
Rotating Electrical Machines	IEC 34
Dimensions and Output Ratings for Rotating Electrical Machines	IEC 72 & 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. 27.

Design Codes – EMC System	
Designed according to	IEC 61400-1: 2005
Further robustness requirements according to	TPS 901795

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 7-5: 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 1kV 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 climatic 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 needed 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 min. average)	42.5 m/s
Survival Wind Speed (3 sec. 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 acc. 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 acc. 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 not 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 as determined by the sensors and control system of the turbine.

Operational Envelope – Temperature and Wind	
Ambient Temperature Interval (Normal Temperature Turbine)	-20° to +40° C
Cut-in (10 min. average)	3 m/s
Cut-out (100 sec. exponential average)	20 m/s
Re-cut in (100 sec. 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}	50 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 sec.	440 V	759 V
Voltage above 115% of nominal for 2 sec.	460 V	794 V
Voltage above 120% of nominal for 0.08 sec.	480 V	828 V
Voltage above 125% of nominal for 0.005 sec	500 V	863 V
Voltage below 90% of nominal for 60 sec.	360 V	621 V
Voltage below 85% of nominal for 11 sec.	340 V	586 V
Frequency is above [Hz] for 0.2 sec.	53 Hz	
Frequency is below [Hz] for 0.2 sec.	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 as illustrated in Figure 9-1, p. 31.

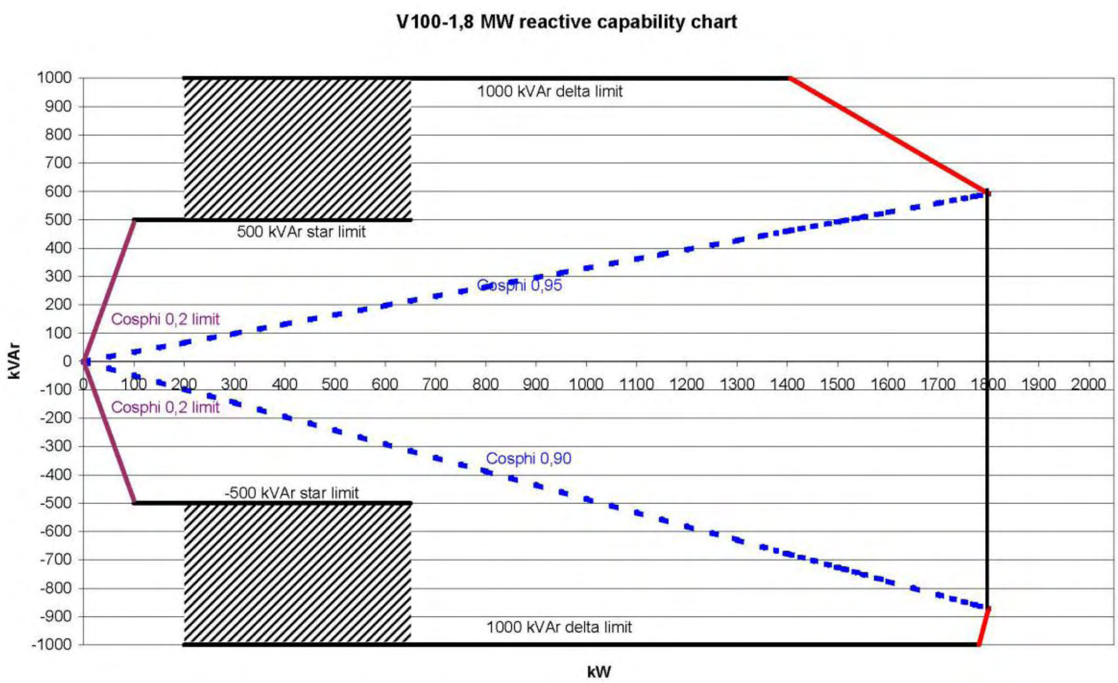

Figure 9-1: Reactive power capability.

The above chart applies at the low voltage side of the HV transformer. Reactive power is produced by the rotor converter; 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 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 9-2, p. 32.

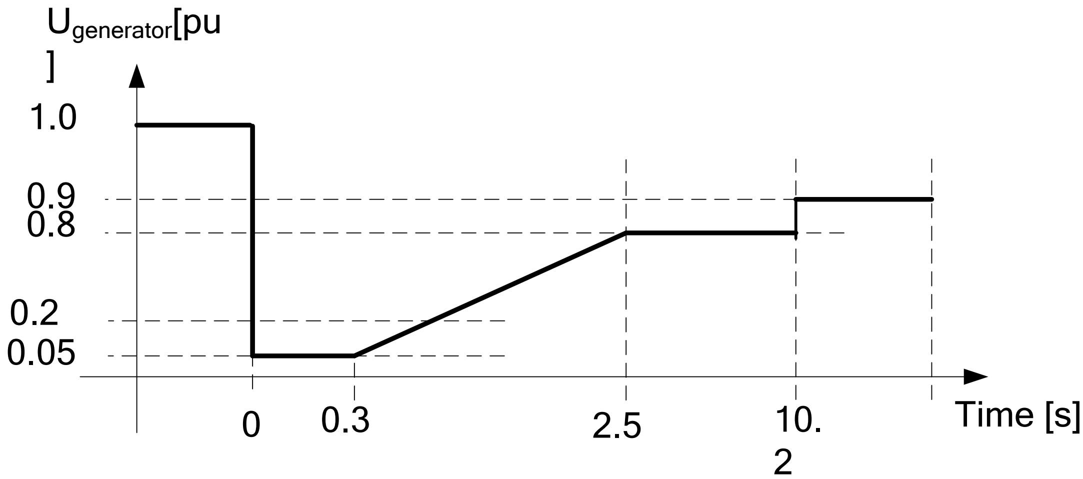

Figure 9-2: Low voltage tolerance curve for symmetrical and asymmetrical faults.

For grid disturbances outside the protection curve in Figure 9-3, p. 33, the turbine will be disconnected from the grid.

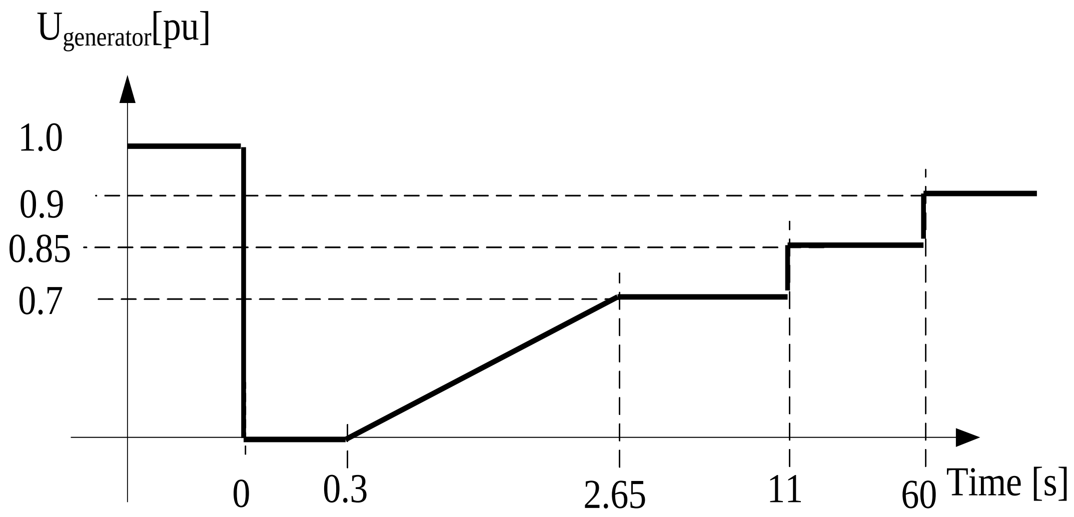

Figure 9-3: Default low voltage protection settings for symmetrical and asymmetrical faults.

Power Recovery Time	
Power recovery to 90% of pre-fault level	Max 1.0 sec

9.6 Performance – Reactive Current Contribution

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

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 (Figure 9-4, p. 34).

The default value gives a reactive current part of 1 pu of the rated turbine current at the generator terminals. Figure 9-4, p. 34 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.

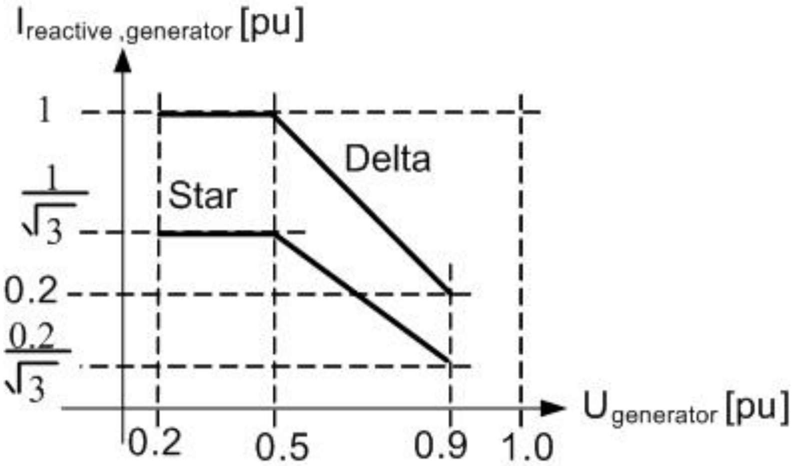

Figure 9-4: Reactive current contribution in star and delta drawn for 100% reactive current contribution.

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 which 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 magnetization 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-phase or phase-ground RMS per unit voltage measured and ’u_{pu_low}’ as the lowest phase-phase or phase-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 6 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/sec
Reactive Power	2.5 pu/sec

To protect the turbine active power cannot be controlled to values below the curve in Figure 9-5, p. 35.

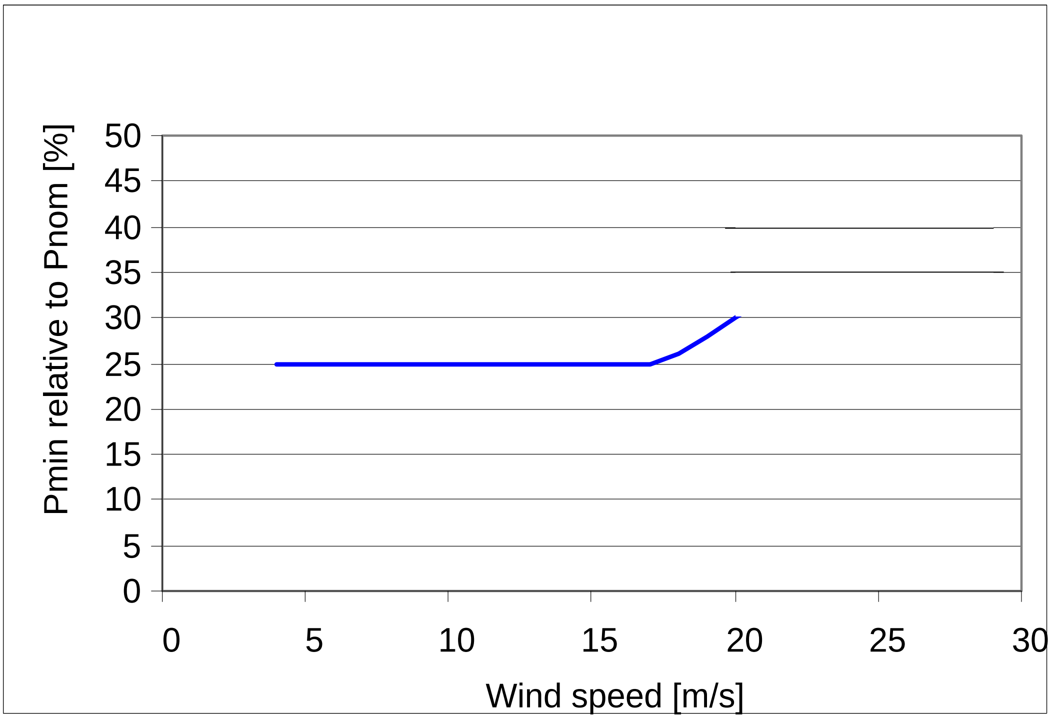

Figure 9-5: Minimum active power output dependant of wind speed.

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).

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

9.11 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 (std) **3 x 6 kW (LT)**	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	Maximum 3.9 kW

Table 9-6: Own consumption data.

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

See appendix section 12.1 Mode 0, p. 40, 12.2 Mode 1, p. 44 and 12.3 Mode 2, p. 48 for power curve, C_t values and noise level.

Conditions for Power Curve, C_t Values (at Hub Height)	
Wind Shear	0.10 - 0.16 (10 min. average)
Turbulence Intensity	8 - 12% (10 min. 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 9-7: Conditions for power curve, C_t values.

10 Drawings

10.1 Structural Design – Illustration of Outer Dimensions

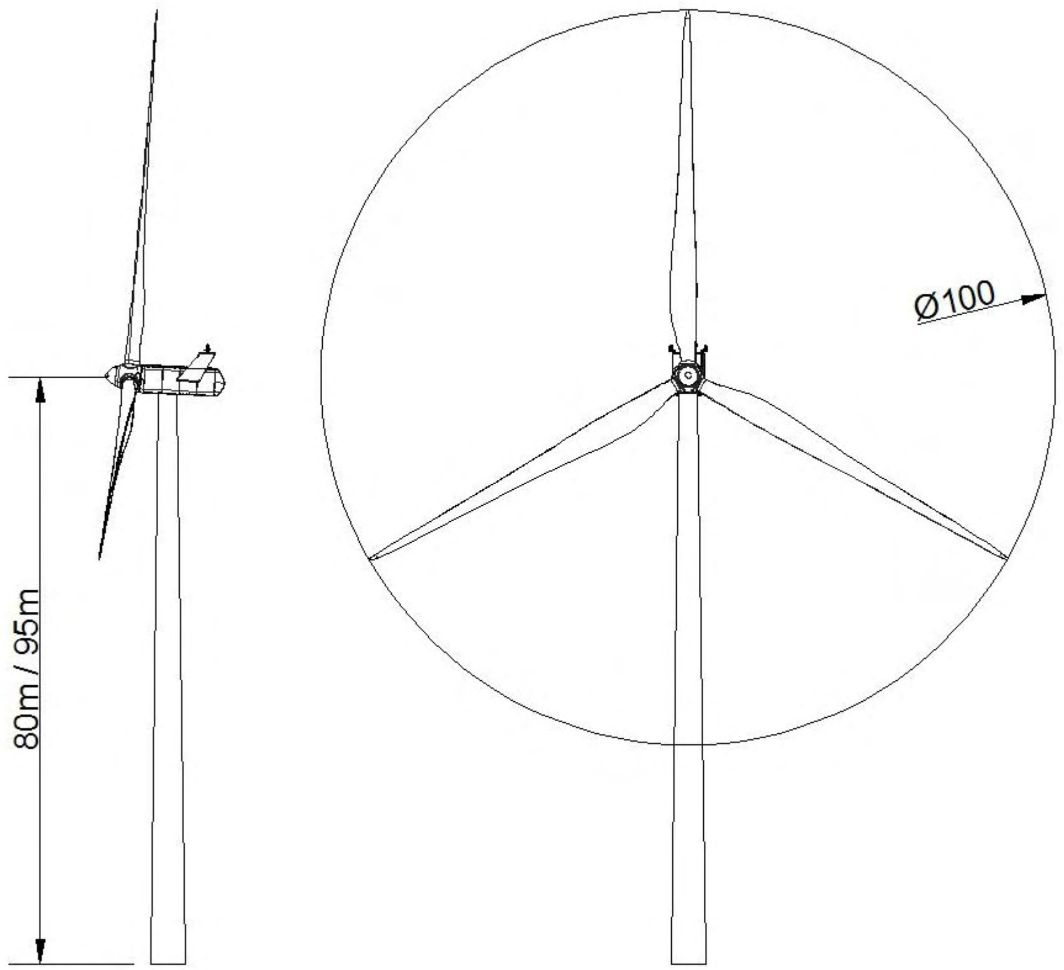

Figure 10-1: Illustration of outer dimensions – structure.

10.2 Structural Design – Side View Drawing

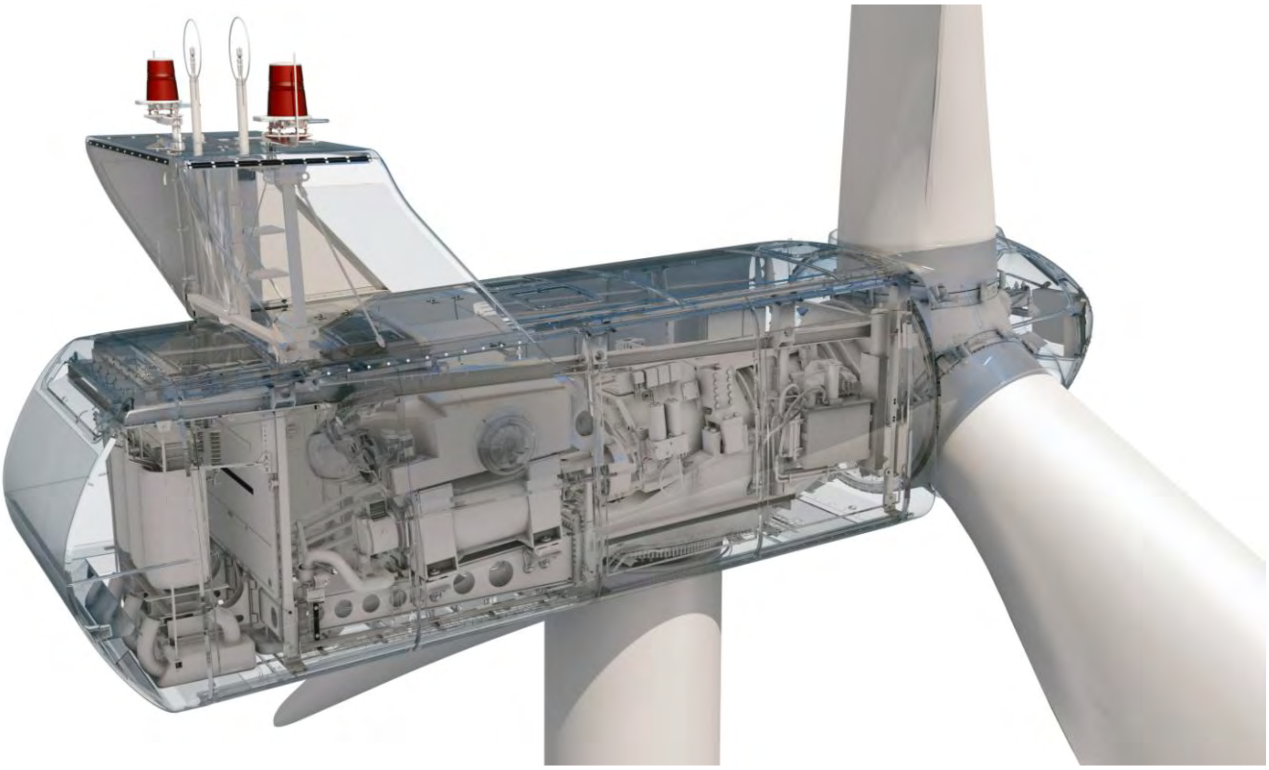

Figure 10-2: Side view drawing.

11 General Reservations, Notes and Disclaimers

- These general specifications 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.
- Periodic operational disturbances and generator power de-rating may be caused by combination of high winds, low voltage or high temperature.
- 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.
- Lightning strikes are considered force majeure, i.e. damage caused by lightning strikes is not warranted by Vestas.
- For the avoidance of doubt, 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 Mode 0 to 2 are defined below.

12.1 Mode 0

12.1.1 Mode 0, Power Curve

Mode 0, Power curves														
	Air density kg/m^3													
Wind speed [m/s]	**1.225**	**0.95**	**0.975**	**1**	**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	13	13	14	14
3.5	**52**	34	36	37	39	41	42	44	45	47	48	50	53	55
4	**108**	79	81	84	87	90	92	95	98	100	103	106	111	114
4.5	**177**	133	137	141	145	149	153	157	161	165	169	173	181	185
5	**256**	195	201	206	212	217	223	229	234	240	245	251	262	268
5.5	**350**	268	275	283	290	298	305	312	320	327	335	342	357	364
6	**458**	353	362	372	382	391	401	410	420	430	439	449	468	477
6.5	**589**	452	464	477	489	502	514	527	539	552	564	576	601	614
7	**744**	573	588	604	620	635	651	666	682	697	713	728	759	774
7.5	**916**	709	728	747	766	785	804	822	841	860	878	897	934	953
8	**1106**	861	884	906	929	952	974	996	1018	1040	1062	1084	1128	1150
8.5	**1312**	1028	1054	1080	1107	1133	1159	1185	1210	1236	1261	1287	1337	1362
9	**1510**	1206	1235	1265	1295	1324	1352	1380	1408	1436	1461	1486	1532	1554
9.5	**1663**	1385	1416	1446	1477	1507	1532	1556	1581	1606	1625	1644	1678	1693
10	**1749**	1551	1575	1600	1625	1649	1666	1683	1699	1716	1727	1738	1757	1764
10.5	**1784**	1673	1689	1705	1721	1737	1746	1754	1763	1772	1776	1780	1786	1789
11	**1796**	1749	1756	1764	1771	1779	1782	1785	1788	1791	1793	1794	1796	1797
11.5	**1799**	1781	1784	1787	1790	1793	1794	1795	1797	1798	1798	1799	1800	1800
12	**1800**	1793	1795	1796	1797	1798	1799	1799	1799	1800	1800	1800	1800	1800
12.5	**1800**	1799	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

Mode 0, Power curves														
	Air density kg/m^3													
Wind speed [m/s]	**1.225**	**0.95**	**0.975**	**1**	**1.025**	**1.05**	**1.075**	**1.1**	**1.125**	**1.15**	**1.175**	**1.2**	**1.25**	**1.275**
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: Mode 0, power curve.

12.1.2 Mode 0, C_t Values

Mode 0, C_t values														
	Air density kg/m^3													
Wind speed [m/s]	**1.225**	**0.95**	**0.975**	**1**	**1.025**	**1.05**	**1.075**	**1.1**	**1.125**	**1.15**	**1.175**	**1.2**	**1.25**	**1.275**
3	**0.868**	0.868	0.868	0.868	0.868	0.868	0.868	0.868	0.868	0.868	0.868	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**	0.882	0.882	0.882	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	**0.826**	0.826	0.826	0.826	0.826	0.826	0.826	0.826	0.826	0.826	0.826	0.826	0.826	0.826
5.5	**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
6	**0.803**	0.803	0.803	0.803	0.803	0.802	0.803	0.803	0.803	0.803	0.803	0.803	0.803	0.803
6.5	**0.819**	0.819	0.819	0.819	0.819	0.819	0.819	0.819	0.819	0.819	0.819	0.819	0.819	0.819
7	**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
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	0.805	0.805
8	**0.792**	0.800	0.800	0.799	0.799	0.798	0.797	0.797	0.796	0.795	0.794	0.793	0.791	0.790
8.5	**0.762**	0.783	0.782	0.780	0.778	0.776	0.774	0.773	0.771	0.769	0.766	0.764	0.759	0.757
9	**0.707**	0.751	0.748	0.745	0.742	0.739	0.735	0.731	0.727	0.723	0.718	0.713	0.701	0.695
9.5	**0.629**	0.704	0.699	0.694	0.688	0.683	0.676	0.669	0.662	0.654	0.646	0.637	0.620	0.611
10	**0.541**	0.648	0.639	0.630	0.622	0.613	0.603	0.593	0.583	0.573	0.562	0.551	0.530	0.520
10.5	**0.457**	0.580	0.569	0.558	0.546	0.535	0.524	0.512	0.501	0.489	0.479	0.468	0.447	0.437
11	**0.387**	0.509	0.496	0.484	0.471	0.459	0.448	0.437	0.426	0.415	0.406	0.396	0.379	0.370
11.5	**0.332**	0.439	0.427	0.416	0.404	0.393	0.383	0.374	0.365	0.355	0.347	0.339	0.325	0.318
12	**0.287**	0.378	0.368	0.359	0.349	0.339	0.331	0.323	0.315	0.307	0.300	0.294	0.281	0.275

Mode 0, C_t values														
	Air density kg/m^3													
Wind speed [m/s]	**1.225**	**0.95**	**0.975**	**1**	**1.025**	**1.05**	**1.075**	**1.1**	**1.125**	**1.15**	**1.175**	**1.2**	**1.25**	**1.275**
12.5	**0.251**	0.329	0.321	0.312	0.304	0.295	0.288	0.282	0.275	0.268	0.262	0.257	0.246	0.241
13	**0.221**	0.288	0.281	0.274	0.266	0.259	0.253	0.247	0.242	0.236	0.231	0.226	0.217	0.213
13.5	**0.197**	0.255	0.248	0.242	0.236	0.230	0.225	0.220	0.214	0.209	0.205	0.201	0.193	0.189
14	**0.176**	0.227	0.221	0.216	0.210	0.205	0.200	0.196	0.191	0.187	0.183	0.179	0.172	0.169
14.5	**0.158**	0.203	0.198	0.193	0.188	0.183	0.180	0.176	0.172	0.168	0.164	0.161	0.155	0.152
15	**0.142**	0.182	0.178	0.174	0.169	0.165	0.161	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	0.149	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**	0.136	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	0.113	0.111	0.109	0.107	0.104	0.102	0.100	0.097	0.095
17.5	**0.091**	0.114	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
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	0.064	0.061	0.060

Table 12-2: Mode 0, C_t values.

12.1.3 Mode 0, Sound Power Levels

Sound Power Level at Hub Height, Mode 0		
Conditions for Sound Power Level	**Verification standard: IEC 61400-11 Ed. 2.** **Wind shear 0.15.** **Max turbulence at 10 meter height: 16%** **Inflow angle (vertical): 0 ± 2°** **Air density: 1.225 kg/m³**	
Hub Height	80 m	95 m
LwA @ 3 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	94.0 4.2	94.1 4.3
LwA @ 4 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	96.2 5.6	96.6 5.7
LwA @ 5 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	100.1 7.0	100.7 7.2
LwA @ 6 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	103.9 8.4	104.4 8.6
LwA @ 7 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	105.0 9.8	105.0 10.0
LwA @ 8 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	105.0 11.2	105.0 11.5
LwA @ 9 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	105.0 12.6	105.0 12.9
LwA @ 10 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	105.0 13.9	105.0 14.3
LwA @ 11 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	105.0 15.3	105.0 15.8
LwA @ 12 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	105.0 16.7	105.0 17.2
LwA @ 13 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	105.0 18.1	105.0 18.6

Table 12-3: Sound power level at hub height: Mode 0.

12.2 Mode 1

12.2.1 Mode 1, Power Curves

Mode 1, Power curves														
	Air density kg/m^3													
Wind speed [m/s]	**1.225**	**0.95**	**0.975**	**1**	**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	13	13	14	14
3.5	**52**	34	36	37	39	41	42	44	45	47	48	50	53	55
4	**108**	78	81	84	87	89	92	95	98	100	103	106	111	114
4.5	**174**	131	135	139	143	147	151	155	159	163	167	170	178	182
5	**250**	190	195	201	206	212	217	223	228	233	239	244	255	261
5.5	**338**	259	266	273	280	288	295	302	309	317	324	331	345	353
6	**445**	342	351	361	370	379	389	398	407	417	426	435	454	463
6.5	**582**	447	459	471	484	496	508	521	533	546	558	570	595	607
7	**736**	567	583	598	613	629	644	660	675	691	706	721	751	767
7.5	**907**	702	721	740	759	777	796	814	833	852	870	889	926	944
8	**1099**	853	876	898	921	943	965	988	1010	1032	1054	1076	1121	1143
8.5	**1307**	1020	1047	1073	1099	1126	1152	1178	1204	1230	1255	1281	1332	1357
9	**1509**	1199	1229	1259	1289	1319	1347	1376	1405	1433	1458	1483	1531	1554
9.5	**1664**	1382	1413	1444	1475	1506	1531	1556	1581	1606	1625	1644	1678	1693
10	**1748**	1549	1574	1599	1624	1650	1666	1683	1700	1717	1727	1738	1755	1762
10.5	**1783**	1672	1688	1705	1721	1738	1746	1755	1763	1772	1776	1779	1785	1787
11	**1796**	1750	1757	1765	1772	1780	1783	1786	1789	1792	1793	1794	1796	1797
11.5	**1799**	1781	1784	1787	1790	1793	1795	1796	1797	1798	1798	1799	1799	1800
12	**1800**	1794	1795	1796	1797	1799	1799	1799	1800	1800	1800	1800	1800	1800
12.5	**1800**	1799	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

Mode 1, Power curves														
	Air density kg/m^3													
Wind speed [m/s]	**1.225**	**0.95**	**0.975**	**1**	**1.025**	**1.05**	**1.075**	**1.1**	**1.125**	**1.15**	**1.175**	**1.2**	**1.25**	**1.275**
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: Mode 1, power curve.

12.2.2 Mode 1, C_t Values

Mode 1, C_t values														
	Air density kg/m^3													
Wind speed [m/s]	**1.225**	**0.95**	**0.975**	**1**	**1.025**	**1.05**	**1.075**	**1.1**	**1.125**	**1.15**	**1.175**	**1.2**	**1.25**	**1.275**
3	**0.868**	0.868	0.868	0.868	0.869	0.869	0.869	0.869	0.868	0.868	0.868	0.868	0.868	0.868
3.5	**0.883**	0.883	0.883	0.883	0.883	0.883	0.883	0.883	0.883	0.883	0.883	0.883	0.883	0.883
4	**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
4.5	**0.792**	0.792	0.792	0.792	0.792	0.792	0.792	0.792	0.792	0.792	0.792	0.792	0.792	0.792
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	0.717	0.717	0.717	0.717	0.717
6	**0.713**	0.713	0.713	0.713	0.713	0.713	0.713	0.713	0.713	0.713	0.713	0.713	0.713	0.713
6.5	**0.763**	0.763	0.763	0.763	0.763	0.763	0.763	0.763	0.763	0.763	0.763	0.763	0.763	0.763
7	**0.757**	0.757	0.757	0.757	0.757	0.757	0.757	0.757	0.757	0.756	0.757	0.757	0.757	0.757
7.5	**0.753**	0.753	0.753	0.753	0.753	0.753	0.753	0.753	0.753	0.753	0.753	0.753	0.753	0.753
8	**0.749**	0.749	0.749	0.749	0.749	0.749	0.749	0.749	0.749	0.749	0.749	0.749	0.749	0.749
8.5	**0.733**	0.743	0.743	0.742	0.741	0.740	0.739	0.738	0.737	0.736	0.735	0.734	0.731	0.730
9	**0.694**	0.725	0.723	0.721	0.719	0.717	0.715	0.712	0.710	0.707	0.703	0.698	0.689	0.683
9.5	**0.625**	0.693	0.689	0.684	0.680	0.676	0.669	0.663	0.656	0.650	0.641	0.633	0.616	0.606
10	**0.539**	0.644	0.636	0.627	0.619	0.611	0.601	0.591	0.581	0.571	0.560	0.549	0.528	0.517
10.5	**0.456**	0.579	0.568	0.557	0.546	0.535	0.523	0.512	0.500	0.489	0.478	0.467	0.446	0.436
11	**0.387**	0.509	0.497	0.484	0.472	0.459	0.448	0.437	0.426	0.415	0.406	0.396	0.378	0.370
11.5	**0.331**	0.439	0.427	0.416	0.404	0.393	0.383	0.374	0.365	0.355	0.347	0.339	0.324	0.317
12	**0.287**	0.378	0.369	0.359	0.349	0.339	0.331	0.323	0.315	0.307	0.300	0.294	0.281	0.275
12.5	**0.251**	0.329	0.321	0.312	0.304	0.295	0.288	0.282	0.275	0.268	0.262	0.257	0.246	0.241
13	**0.221**	0.288	0.281	0.274	0.266	0.259	0.253	0.247	0.242	0.236	0.231	0.226	0.217	0.213
13.5	**0.197**	0.255	0.248	0.242	0.236	0.230	0.225	0.220	0.214	0.209	0.205	0.201	0.193	0.189
14	**0.176**	0.227	0.221	0.216	0.210	0.205	0.200	0.196	0.191	0.187	0.183	0.179	0.172	0.169

Mode 1, C_t values														
	Air density kg/m^3													
Wind speed [m/s]	**1.225**	**0.95**	**0.975**	**1**	**1.025**	**1.05**	**1.075**	**1.1**	**1.125**	**1.15**	**1.175**	**1.2**	**1.25**	**1.275**
14.5	**0.158**	0.203	0.198	0.193	0.188	0.183	0.180	0.176	0.172	0.168	0.164	0.161	0.155	0.152
15	**0.142**	0.182	0.178	0.174	0.169	0.165	0.161	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	0.149	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**	0.136	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	0.113	0.111	0.109	0.107	0.104	0.102	0.100	0.097	0.095
17.5	**0.091**	0.114	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
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	0.064	0.061	0.060

Table 12-5: Mode 1, C_t values.

12.2.3 Mode 1, Sound Power Levels

Sound Power Level at Hub Height, Mode 1		
Conditions for Sound Power Level	**Verification standard: IEC 61400-11 Ed. 2.** **Wind shear 0.15** **Max turbulence at 10 meter 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 hh [m/sec]	94.0 4.2	94.0 4.3
LwA @ 4 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	95.4 5.6	95.6 5.7
LwA @ 5 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	99.1 7.0	99.7 7.2
LwA @ 6 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	102.9 8.4	103.4 8.6
LwA @ 7 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	105.0 9.8	105.0 10.0
LwA @ 8 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	105.0 11.2	105.0 11.5
LwA @ 9 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	105.0 12.6	105.0 12.9
LwA @ 10 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	105.0 13.9	105.0 14.3
LwA @ 11 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	105.0 15.3	105.0 15.8
LwA @ 12 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	105.0 16.7	105.0 17.2
LwA @ 13 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	105.0 18.1	105.0 18.6

Table 12-6: Sound power level at hub height: Mode 1.

12.3 Mode 2

12.3.1 Mode 2, Power Curves

Mode 2, Power curves														
	Air density kg/m^3													
Wind speed [m/s]	**1.225**	**0.95**	**0.975**	**1**	**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	13	13	14	14
3.5	**52**	34	36	37	39	41	42	44	45	47	48	50	53	55
4	**108**	79	81	84	87	90	92	95	98	100	103	106	111	114
4.5	**177**	133	137	141	145	149	153	157	161	165	169	173	181	185
5	**256**	195	201	206	212	217	223	229	234	240	245	251	262	268
5.5	**349**	268	275	282	290	297	305	312	320	327	335	342	357	364
6	**458**	352	362	372	381	391	401	410	420	429	439	448	467	477
6.5	**589**	452	464	477	489	502	514	527	539	552	564	576	601	614
7	**743**	572	588	604	619	635	650	666	681	697	712	728	758	774
7.5	**913**	706	725	744	763	782	801	820	838	857	875	894	931	950
8	**1091**	848	870	892	914	937	959	981	1002	1024	1047	1069	1113	1135
8.5	**1268**	985	1011	1037	1062	1088	1114	1140	1165	1191	1217	1243	1294	1320
9	**1428**	1109	1138	1167	1196	1225	1255	1284	1313	1342	1371	1399	1455	1483
9.5	**1549**	1209	1240	1272	1304	1336	1367	1399	1430	1461	1490	1519	1574	1599
10	**1629**	1285	1319	1353	1387	1421	1453	1484	1516	1548	1575	1602	1650	1672
10.5	**1686**	1346	1381	1416	1451	1486	1517	1548	1580	1611	1636	1661	1704	1722
11	**1732**	1411	1446	1481	1517	1552	1582	1611	1641	1671	1691	1712	1744	1757
11.5	**1763**	1484	1519	1553	1588	1622	1648	1673	1698	1723	1736	1750	1771	1778
12	**1783**	1572	1603	1633	1663	1693	1710	1727	1743	1760	1767	1775	1786	1789
12.5	**1792**	1659	1680	1702	1723	1744	1753	1763	1772	1782	1785	1789	1794	1795
13	**1796**	1725	1737	1749	1761	1774	1778	1783	1787	1792	1793	1795	1797	1798
13.5	**1800**	1757	1765	1773	1780	1788	1791	1793	1796	1798	1799	1799	1800	1800
14	**1800**	1784	1787	1791	1794	1798	1798	1799	1799	1800	1800	1800	1800	1800
14.5	**1800**	1797	1798	1798	1799	1800	1800	1800	1800	1800	1800	1800	1800	1800
15	**1800**	1797	1798	1798	1799	1799	1800	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

Mode 2, Power curves														
	Air density kg/m³													
Wind speed [m/s]	**1.225**	**0.95**	**0.975**	**1**	**1.025**	**1.05**	**1.075**	**1.1**	**1.125**	**1.15**	**1.175**	**1.2**	**1.25**	**1.275**
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: Mode 2, power curve.

12.3.2 Mode 2, C_t Values

Mode 2, C_t values														
	Air density kg/m³													
Wind speed [m/s]	**1.225**	**0.95**	**0.975**	**1**	**1.025**	**1.05**	**1.075**	**1.1**	**1.125**	**1.15**	**1.175**	**1.2**	**1.25**	**1.275**
3	0.868	0.868	0.868	0.868	0.868	0.868	0.868	0.868	0.868	0.868	0.868	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	0.882	0.882	0.882	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	0.825	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	0.805	0.805	0.805	0.805	0.805	0.805	0.805	0.805	0.805	0.805	0.805	0.805	0.805	0.805
6	0.799	0.799	0.799	0.799	0.799	0.799	0.799	0.799	0.799	0.799	0.799	0.799	0.799	0.799
6.5	0.817	0.817	0.817	0.817	0.817	0.817	0.817	0.817	0.817	0.817	0.817	0.817	0.817	0.817
7	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
7.5	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785
8	0.749	0.749	0.749	0.749	0.749	0.748	0.748	0.749	0.749	0.749	0.749	0.749	0.749	0.749
8.5	0.696	0.696	0.696	0.696	0.696	0.696	0.696	0.696	0.696	0.696	0.696	0.696	0.696	0.696
9	0.632	0.632	0.632	0.632	0.632	0.632	0.632	0.632	0.633	0.633	0.632	0.632	0.631	0.630
9.5	0.558	0.563	0.563	0.563	0.563	0.563	0.563	0.562	0.562	0.562	0.561	0.560	0.556	0.553
10	0.486	0.496	0.496	0.496	0.496	0.496	0.496	0.495	0.494	0.493	0.491	0.488	0.482	0.478
10.5	0.421	0.437	0.436	0.436	0.436	0.436	0.434	0.433	0.432	0.430	0.427	0.424	0.417	0.412
11	0.367	0.388	0.387	0.387	0.386	0.386	0.384	0.382	0.380	0.378	0.375	0.371	0.362	0.357
11.5	0.322	0.350	0.349	0.348	0.347	0.346	0.343	0.341	0.338	0.335	0.331	0.326	0.317	0.311
12	0.283	0.322	0.320	0.318	0.316	0.314	0.310	0.306	0.302	0.298	0.293	0.288	0.278	0.272
12.5	0.249	0.297	0.294	0.290	0.287	0.283	0.278	0.274	0.269	0.264	0.259	0.254	0.244	0.240
13	0.221	0.273	0.268	0.263	0.259	0.254	0.249	0.244	0.239	0.234	0.230	0.225	0.216	0.212
13.5	0.197	0.247	0.242	0.237	0.233	0.228	0.223	0.218	0.214	0.209	0.205	0.201	0.193	0.189
14	0.176	0.224	0.219	0.214	0.209	0.204	0.200	0.196	0.191	0.187	0.183	0.179	0.172	0.169

Mode 2, C_t values														
	Air density kg/m^3													
Wind speed [m/s]	**1.225**	**0.95**	**0.975**	**1**	**1.025**	**1.05**	**1.075**	**1.1**	**1.125**	**1.15**	**1.175**	**1.2**	**1.25**	**1.275**
14.5	0.158	0.202	0.198	0.193	0.188	0.183	0.180	0.176	0.172	0.168	0.164	0.161	0.155	0.152
15	0.142	0.182	0.177	0.173	0.169	0.165	0.161	0.158	0.155	0.151	0.148	0.145	0.140	0.137
15.5	0.129	0.164	0.161	0.157	0.153	0.149	0.146	0.143	0.140	0.137	0.134	0.132	0.127	0.124
16	0.117	0.149	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	0.136	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	0.113	0.111	0.109	0.107	0.104	0.102	0.100	0.097	0.095
17.5	0.091	0.114	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
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	0.064	0.061	0.060

Table 12-8: Mode 2, C_t values.

12.3.3 Mode 2, Sound Power Levels

Sound Power Level at Hub Height, Mode 2		
Conditions for Sound Power Level	**Verification standard: IEC 61400-11 Ed. 2.** **Wind shear 0.15** **Max turbulence at 10 meter 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 hh [m/sec]	94.0 4.2	94.1 4.3
LwA @ 4 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	96.2 5.6	96.6 5.7
LwA @ 5 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	100.1 7.0	100.7 7.2
LwA @ 6 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	103.0 8.4	103.0 8.6
LwA @ 7 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	103.0 9.8	103.0 10.0
LwA @ 8 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	103.0 11.2	103.0 11.5
LwA @ 9 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	103.0 12.6	103.0 12.9
LwA @ 10 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	103.0 13.9	103.0 14.3
LwA @ 11 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	103.0 15.3	103.0 15.8
LwA @ 12 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	103.0 16.7	103.0 17.2
LwA @ 13 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	103.0 18.1	103.0 18.6

Table 12-9: Sound power level at hub height: Mode 2.

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DELTA Test Report

ilac-MRA DANAK
TEST Reg. no. 100

Measurement of Noise Emission from a Vestas V100 - 1.8 MW VCS Wind Turbine

Performed for Vestas Wind Systems A/S

AV 172/10
DANAK 100/2791
Project no.: A581534
Page 1 of 24
10 graph sheets and
5 annexes

29 October 2010

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Title

Measurement of Noise Emission from a
Vestas V100 - 1.8 MW VCS Wind Turbine

Journal no.	Project no.	Our ref.	Date of test
AV 172/10 DANAK 100/2791	A581528	LSS-KDM/ugn	25 September 2010, 14 and 15 October 2010

Client

Vestas Wind Systems A/S
Hedeager 42
8200 Århus N
Denmark

Client ref.

Jan Johansen

Summary

The noise emission from a Vestas V100 – 1.8 MW VCS wind turbine, situated at Høvsøre, Denmark has been determined. The measurement results are shown in the table below.

Wind speed [m/s]	6	7	8	9	10	11
Power [kW]	1593	1786	1797	1799	1798	1800
$L_{WA, Polynomial}$ [dB re 1 pW]	104.3	104.3	103.9	103.8	104.4	105.3
Tonal Audibility ΔL_a [dB]	-3.9	-10.4	-10.7	-10.2	-5.2	-9.3

Remark

The test results apply only to the object tested.

DELTA, 29 October 2010

Kaj Dam Madsen
Acoustics

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DELTA

1. Test Situation

1.1 Test Object

The turbine is a Vestas V100 – 1.8 MW VCS wind turbine with a hub height of 106 m above the surrounding ground. The turbine has a rotor diameter of 100 m. Specifications for the wind turbine is shown in Annex 3.

1.2 Test Site

The wind turbine is situated in flat terrain at the Risø DTU test site at Høvsøre, Denmark.

Photos from the site are shown in annex 1 and 2.

2. Measurement Conditions and Procedure

The measurements were performed on the 25th September 2010, the 14th October and the 15th October 2010 with the meteorological conditions stated below:

Date	25th September	14th October	15th October
Time period	1 pm to 7 pm	00.40 pm to 12 pm	00.00 am to 00.40 am and 4.40 am to 5.40 am
Wind speed	3 – 7 m/s	7 - 11	5 - 8
Average wind direction	North East, ~ 70°	North West, ~ 340°	North West, ~ 340°
Cloudiness	2/8 – 3/8	2/8 - 5/8	2/8 – 5/8
Air temperature	~ 8-12 °C	~ 6 -12 °C	~ 6 -8 °C
Relative Humidity	80 % RH	70 % RH	70 % RH
Barometric pressure	1000 mbar	1012 mbar	1012 mbar

The measurements were performed in accordance with IEC 61400-11:2002 "Wind turbine generator systems - Part 11: Acoustic noise measurement techniques" Edition 2.1.

The noise was measured at a horizontal distance of 155 m from the turbine hub at the reference position as described in figure 3 of IEC 61400-11.

The measurement microphone was mounted with a cut-through windscreen placed directly on a 12 mm circular plywood board with a diameter of 1.0 m (+6 dB measurement). The board was placed directly at the ground. A secondary wind shield type, DELTA H, was used during the measurements.

The wind speed and direction were measured in front of the turbine at a distance of approx. 170 m from the turbine, and the electrical power produced by the turbine, the nacelle wind speed and the rotor RPM were registered through the wind turbine controller.

The data was registered online with the measurement program Wind Turbine 2.0 developed by DELTA.

The background noise was measured with the turbine parked. The background noise was primarily wind-induced noise in the surroundings.

The noise from the turbine was primarily aerodynamic noise. There was no significant noise from yawing or other single events during measurements.

The measurements of the equivalent noise level in one-third octave bands, produced electrical power and wind speed were averaged synchronously over one-minute periods for the entire measurement period. 10 second FFT spectra were made as well.

From the power curve and a roughness length of $z_0 = 0.05$ m, the produced electrical power data were converted into a wind speed at a height of 10 m. The power curve given by Vestas is shown in Annex 4.

Periods influenced by intruding intermittent background noise (cars, planes etc.) were discarded when analyzing the measurements.

3. Measurement Equipment

The measurement equipment is specified in Annex 5.

4. Measurement Results

4.1 Measured Wind Speed

A conversion factor κ is determined as the average value of the ratio of the calculated wind speed ($v_{p,10}$) and the measured wind speed for simultaneous periods for the nacelle anemometer ($v_{Nac,10}$) and for the 10 m anemometer (v_{Anem}).

$$\kappa_{Anem} = v_{p,10}/v_{Anem}$$

$$\kappa_{Nac} = v_{p,10}/v_{Nac,10}$$

The normalized wind speed during background noise measurements is calculated as:

$$v_{Anem,kor} = \kappa_{Anem} \cdot v_{Anem}$$

The normalized wind speed used above 95% of rated power is calculated as:

$$v_{Nac,kor} = \kappa_{Nac} \cdot v_{Nac,10}$$

The conversion factors, κ, were determined as shown in Table 1.

	25th September	14th and 15th October
κ_{Anem}-factor	0.87	1.20
κ_{Nac}-factor	0.97	0.94

Table 1 κ -factors

4.2 Sound Pressure Level

The total A-weighted sound pressure levels are calculated from the measured one-third octave band spectra corrected for the influence of the secondary wind shield. The results are shown in the Graph Sheets 1 – 3 together with the background noise as a function of the wind speed. A linear regression is applied to the background noise and used for background noise correction. All spectra in the report are A-weighted.

The A-weighted sound pressure levels generated by the wind turbine as well as the regression analysis are also shown in the Graph Sheets. The measurement results are corrected for background noise. A 4th order regression is applied to the measurement data. Statistics of the measurement results in bins are also shown in the tables below. The term "BIN Class" describes here integer wind speed, 1 m/s wide, open on the low end, closed on the high end.

95 % of rated power is reached at approx. 7 m/s at 10 m height.

Table 2 shows statistics of the measured noise 2010 with the turbine in operation.

BIN Class [m/s]	6	7	8	9	10	11
Number of measurements	15	30	119	153	51	14
Average wind speed [m/s]	6.4	7.2	8.2	9.0	9.9	11.0
Average power [kW]	1593	1786	1797	1799	1798	1800

Table 2 Statistics of the measured noise levels with wind turbine in operation.

Table 3 shows statistics of the measured noise levels with the wind turbine parked.

BIN Class [m/s]	6	7	8	9	10	11
Number of measurements	1	1	6	9	16	6
Average wind speed [m/s]	5.7	7.7	8.0	8.9	10.0	10.8

Table 3 Statistics of the measured noise levels with the wind turbine parked.

Measurement results from the 25th September 2010 are only used for the 6 m/s bin to supply with measurements in the low end of this bin.

Total noise calculated from a 4th order polynomial regression, background noise calculated from a 1st order polynomial regression and the results corrected for background noise are shown in Table 4.

BIN Class [m/s]	6	7	8	9	10	11
$L_{Aeq,t\ Polynomial}$ [dB re 20μPa]	54.2	54.3	54.0	54.1	54.6	55.6
$L_{Aeq,b\ Polynomial}$ [dB re 20μPa]	42.6	43.6	44.7	45.7	46.8	47.8
$L_{Aeq,c\ Polynomial}$ [dB re 20μPa]	53.9	53.9	53.5	53.4	53.8	54.8

Table 4 Measurement results: Total noise ($L_{Aeq,t\ Polynomial}$), background noise ($L_{Aeq,b\ Polynomial}$) and the total noise corrected for background noise ($L_{Aeq,c\ Polynomial}$).

The regression coefficients are shown in Table 5.

The measurement results appear from Graph Sheet No. 1-3.

	4th order	3rd order	2nd order	1st order	Constant
Background noise data	-	-	-	1.04	36.34
Total noise data	-0.0165	0.6005	-7.9142	44.945	-38.911
Corrected measurement data	-0.01812	0.661	-8.7292	49.548	-48.441

Table 5 Regression analysis coefficients.

4.3 Directivity

No measurement of the directivity was made.

4.4 Tonality

The audibility of tones in the noise was analyzed at the reference measurement position at a distance of 155 m from the turbine. The analysis showed possible tones at approximately 223 Hz, 533 Hz, 571 Hz, 698 Hz and 705 Hz. The frequency spectra are shown in graph sheets 5-10. The corresponding audibility's are stated in Table 6.

BIN Class [m/s]	6	7	8	9	10	11
Reference position	-3.9	-10.4	-10.7	-10.2	-5.2	-9.3

Table 6 Tonal audibility ΔL_a [dB]

The measurements were made close to the turbine (155 m), and the measured tonality is not directly applicable at larger distances.

5. Calculation of Sound Power Levels

5.1 Sound Power Level

The emission-relevant sound power level, $L_{WA,ref}$, of the turbine has been calculated according to DS/EN61400-11, based on the assumption that the noise is radiated from a point source at hub height.

$$L_{WA} = L_{Aeq,c} + 10 \cdot \log\left(4\pi\left(R_i^2\right)\right) - 6\text{ dB}$$

Where: R_i = the slant distance from centre of rotor to microphone [m]

The sound power level from the reference position is shown in Table 7.

Wind speed [m/s]	6	7	8	9	10	11
Power [kW]	1593	1786	1797	1799	1798	1800
$L_{WA, Polynomial}$ [dB re 1 pW]	104.3	104.3	103.9	103.8	104.4	105.3

Table 7 Sound power level L_{WA} [dB re 1 pW]

The average sound power levels, in one-third octave bands, are shown in Graph Sheet No. 4.

6. Measurement Uncertainty

The standard uncertainty of L_{WA} calculated according to Annex D of DS/EN 61400-11:2002 "Wind turbine generator systems: Part 11: Acoustic noise measurement techniques" is listed in Table 8.

Wind speed [m/s]	6	7	8	9	10	11
Standard uncertainty	0.8	0.8	0.8	0.8	0.8	0.9

Table 8 Standard uncertainty [dB]

7. Conclusion

The noise emission from a Vestas V100 wind turbine, situated at the Risø DTU test site at Høvsøre, Denmark has been determined. The measurement results are shown in Table 9.

Wind speed [m/s]	6	7	8	9	10	11
Power [kW]	1593	1786	1797	1799	1798	1800
$L_{WA, Polynomial}$ [dB re 1 pW]	104.3	104.3	103.9	103.8	104.4	105.3
Tonal Audibility ΔL_a [dB]	-3.9	-10.4	-10.7	-10.2	-5.2	-9.3

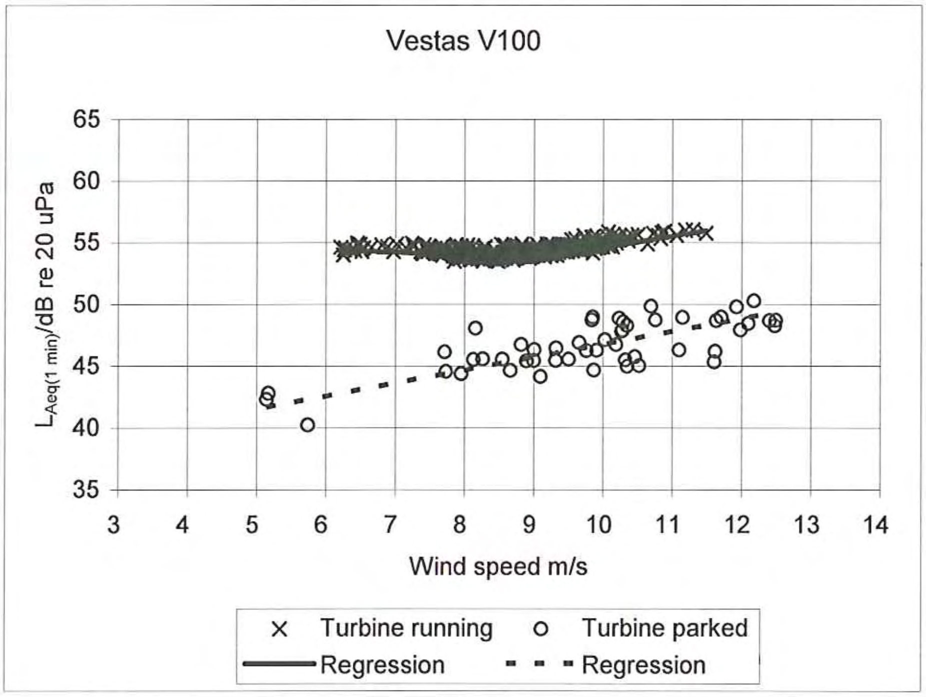
Table 9 Sound power level L_{WA} [dB re 1 pW] from Reference position.

The results were obtained at 155 m distance from the turbine. At larger distances the tonality may be different.

There was no significant noise from yawing or other single events during measurements.

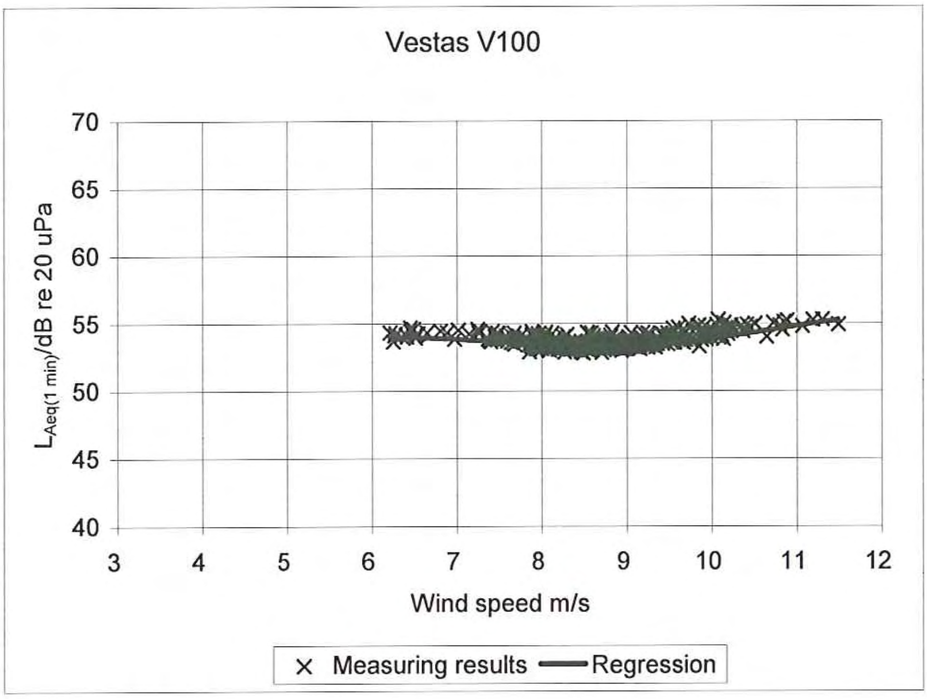
Graph Sheet 1: Measurement results from reference position

Measuring Object	Vestas V100
	Høvsøre
Test date	25th September, 14th and 15th October 2010



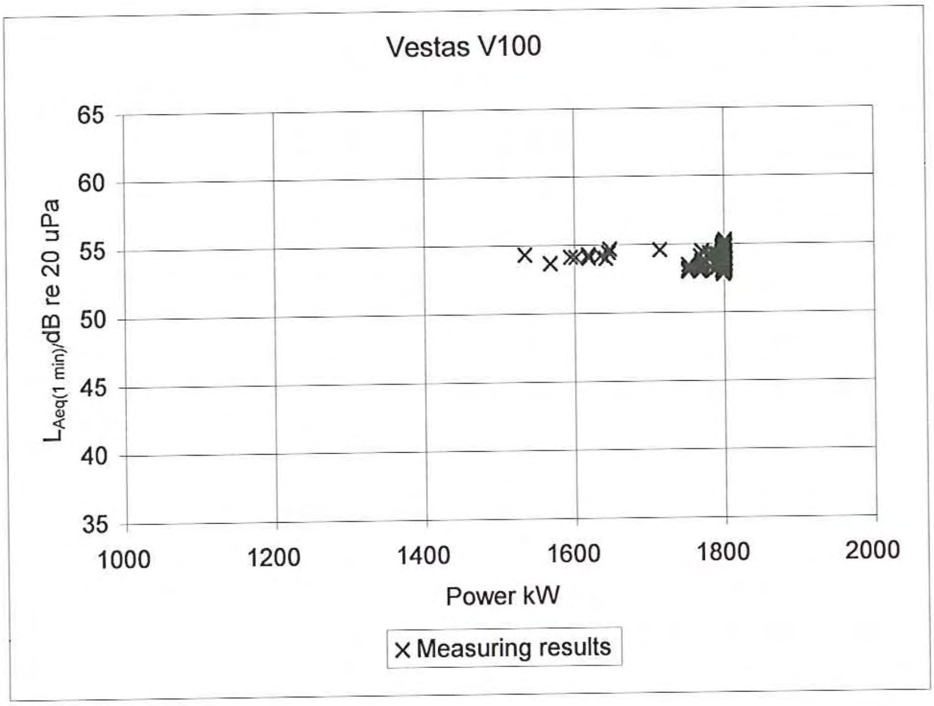
Graph Sheet 2: Measurement results corrected for background noise

Measuring Object	Vestas V100
	Høvsøre
Test date	25th September, 14th and 15th October 2010



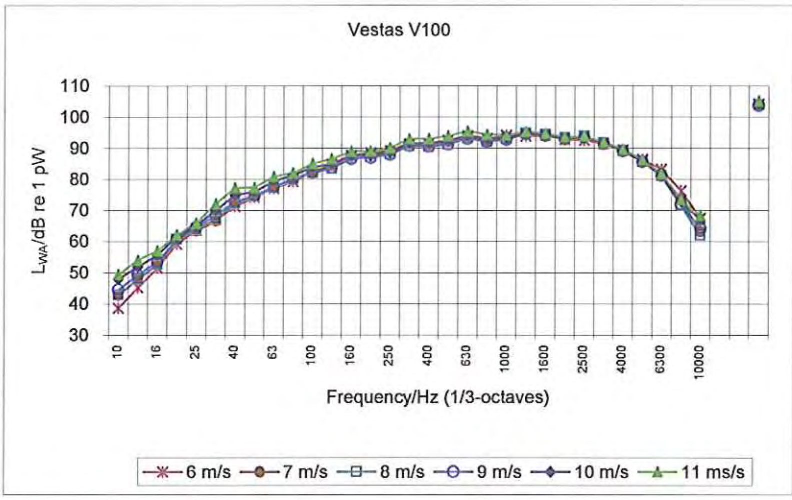
Graph Sheet 3: Measurement results from reference position vs. power corrected for background noise

Measuring Object	Vestas V100
	Høvsøre
Test date	25th September, 14th and 15th October 2010



Graph Sheet 4: 1/3-octave band spectra from reference position

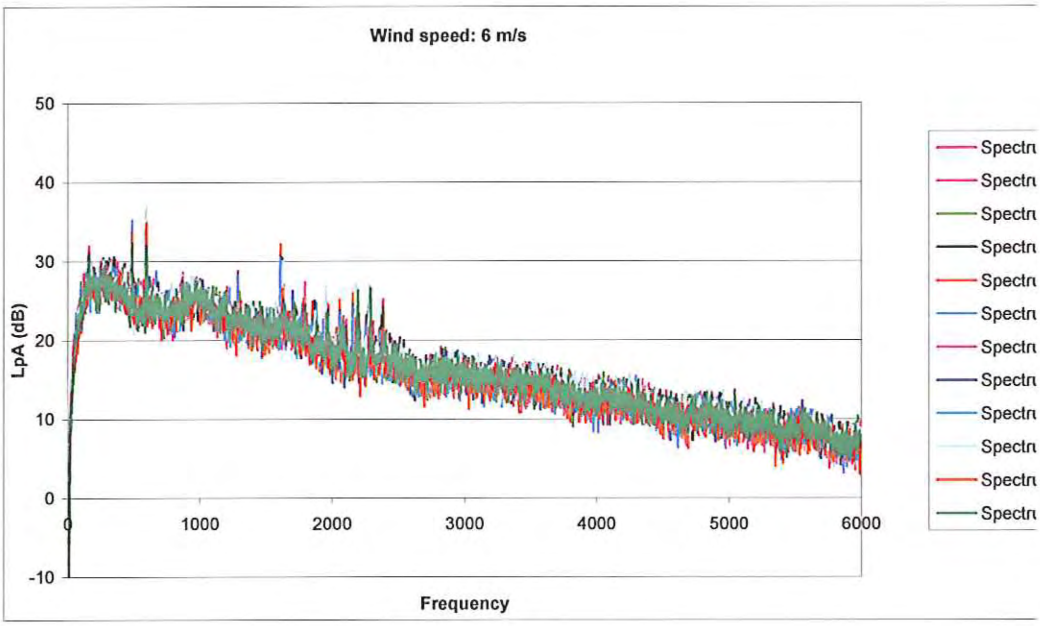
Numbers in *Italic* indicates that the difference between total noise and background noise was less than 3 dB.



Frequency	6 m/s	7 m/s	8 m/s	9 m/s	10 m/s	11 ms/s
10	38.8	42.8	43.0	44.7	48.1	49.5
12.5	45.4	47.9	48.1	49.4	52.0	54.1
16	51.6	52.6	52.7	53.7	55.8	57.1
20	59.4	60.6	60.7	60.9	61.6	62.2
25	63.9	63.6	64.1	64.7	65.4	66.0
31.5	67.2	66.9	67.3	68.7	70.2	72.2
40	71.4	72.3	72.4	72.9	75.0	77.3
50	74.4	74.7	74.7	74.8	76.1	77.4
63	77.2	77.5	77.3	77.7	79.5	80.9
80	79.4	80.3	80.2	80.2	81.5	82.1
100	82.6	82.5	82.1	82.4	83.9	85.1
125	85.0	84.6	83.5	83.9	85.1	86.7
160	87.9	87.8	86.8	86.7	87.7	89.0
200	88.5	88.2	87.1	87.0	87.8	89.1
250	89.3	89.4	88.1	88.0	88.7	90.1
315	91.5	91.7	90.7	90.9	91.6	93.0
400	91.6	91.4	90.5	90.7	91.7	93.1
500	92.7	92.2	91.2	91.3	92.4	94.0
630	94.2	93.8	93.2	93.1	94.0	95.5
800	93.3	92.7	92.1	92.2	93.0	94.4
1000	94.3	93.6	92.9	92.8	93.3	94.3
1250	94.0	94.8	94.9	94.6	94.8	95.4
1600	94.2	94.5	94.4	94.1	94.2	94.8
2000	93.0	93.3	93.3	93.1	93.2	93.7
2500	92.7	93.5	93.8	93.6	93.7	93.9
3150	91.6	91.7	91.7	91.6	91.8	92.0
4000	89.5	89.2	89.2	89.2	89.5	89.7
5000	86.5	85.8	85.7	85.8	86.0	86.3
6300	83.3	81.9	81.2	81.3	81.7	81.9
8000	76.5	73.8	71.6	72.2	73.0	73.6
10000	67.7	63.4	*62.1*	64.3	67.0	68.5
L_{WA}	104.3	104.3	103.9	103.8	104.4	105.3

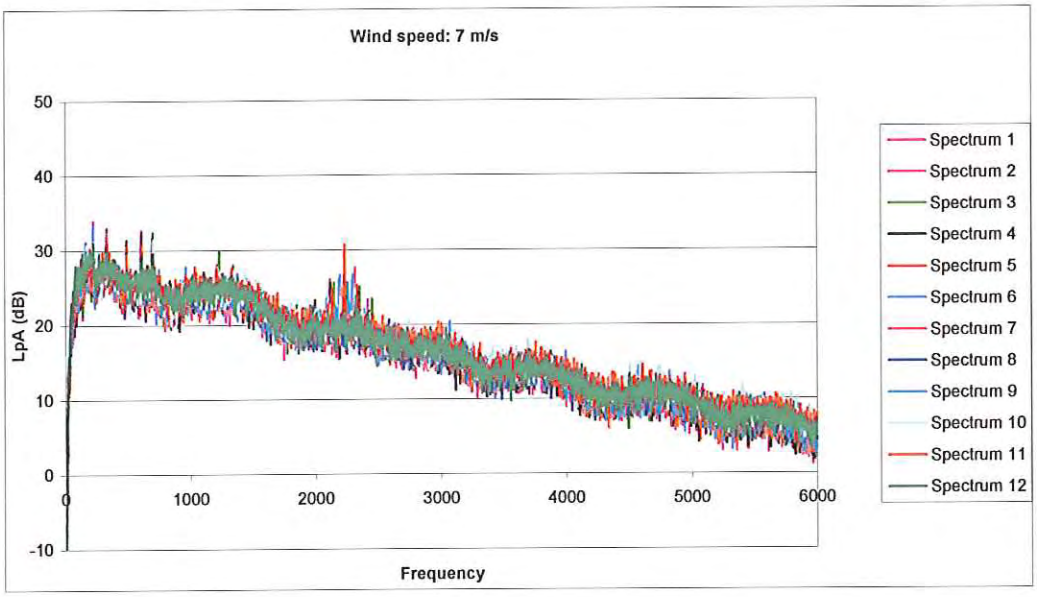
Graph Sheet 5: Tonality analysis at 6 m/s

							Vestas V100					
Linespacing (analysis bandwidth)	2.0 Hz					Wind speed:			6 m/s			
Spectrum no	1	2	3	4	5	6	7	8	9	10	11	12
Frequency/*Hz*	597	599	599	597	593	593	599	597	597	597	599	601
Lp,tone/*dB re 20 uPa*		35.9	37.4	35.1	34.0	34.5	37.1	30.2	36.2	37.8	35.7	32.5
Critical bandwidth/*dB re 20 uPa*	124.2	124.3	124.3	124.2	123.9	123.9	124.3	124.2	124.2	124.2	124.3	124.5
Lower frequency/*dB re 20 uPa*	535	537	537	535	531	531	537	535	535	535	537	539
Upper frequency/*dB re 20 uPa*	659	661	661	659	655	655	661	659	659	659	661	663
Lp,noise,avg/*dB re 20 uPa*		26.1	25.9	25.6	25.1	25.6	25.1	25.9	25.0	25.4	24.6	24.4
10*log(Critical bandwidth/Analysis bandwidth)	16.2	16.2	16.2	16.2	16.2	16.2	16.2	16.2	16.2	16.2	16.2	16.2
Lp,critical band/*dB re 20 uPa*		42.3	42.1	41.8	41.3	41.8	41.3	42.1	41.2	41.6	40.8	40.6
-Ltn	**-16.2**	**-6.4**	**-4.7**	**-6.7**	**-7.3**	**-7.3**	**-4.2**	**-11.9**	**-5.0**	**-3.8**	**-5.1**	**-8.1**
-La	**-13.8**	**-4.0**	**-2.3**	**-4.3**	**-4.9**	**-4.9**	**-1.8**	**-9.5**	**-2.6**	**-1.4**	**-2.7**	**-5.7**



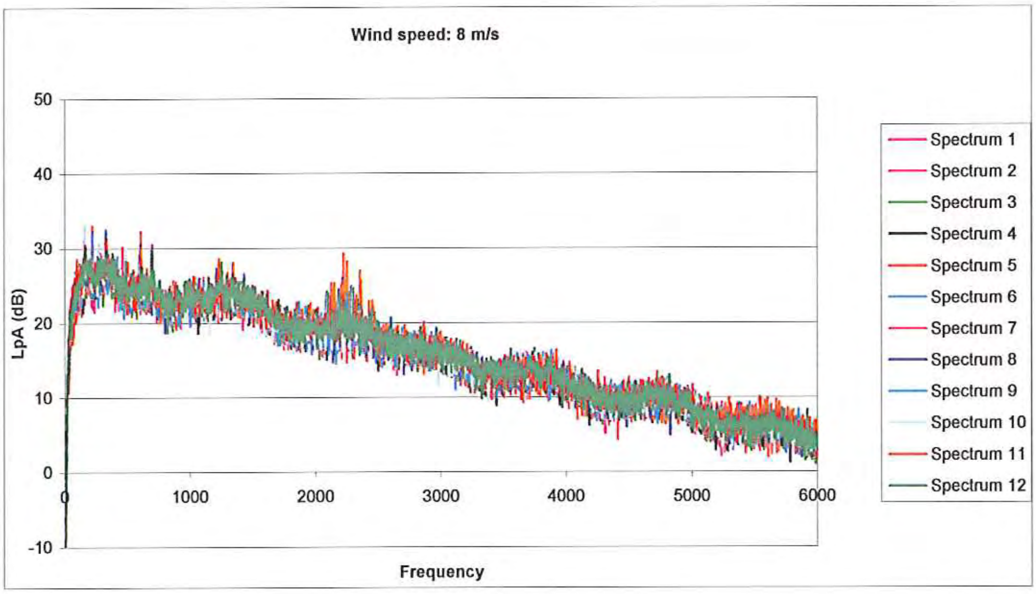
Graph Sheet 6: Tonality analysis at 7 m/s

Linespacing (analysis bandwidth)	2,0 Hz	Vestas V100 Wind speed: 7 m/s											
Spectrum no	1	2	3	4	5	6	7	8	9	10	11	12	Avg
Frequency/*Hz*	698	697	699	697	698	698	698	698	698	698	698	698	
Lp,tone/*dB re 20 uPa*		29,4	33,6	32,9									
Critical bandwidth/*dB re 20 uPa*	132,4	132,3	132,5	132,3	132,4	132,4	132,4	132,4	132,4	132,4	132,4	132,4	
Lower frequency/*dB re 20 uPa*	632	631	633	631	632	632	632	632	632	632	632	632	
Upper frequency/*dB re 20 uPa*	764	763	765	763	764	764	764	764	764	764	764	764	
Lp,noise,avg/*dB re 20 uPa*		25,0	24,7	24,4									
10*log(Critical bandwidth/Analysis bandwidth)	16,4	16,4	16,4	16,4	16,4	16,4	16,4	16,4	16,4	16,4	16,4	16,4	
Lp,critical band/*dB re 20 uPa*		41,4	41,1	40,8									
♦Ltn	-16,4	-12,0	-7,5	-7,9	-16,4	-16,4	-16,4	-16,4	-16,4	-16,4	-16,4	-16,4	-13,0
♦La	-13,9	-9,5	-5,0	-5,4	-13,9	-13,9	-13,9	-13,9	-13,9	-13,9	-13,9	-13,9	-10,4



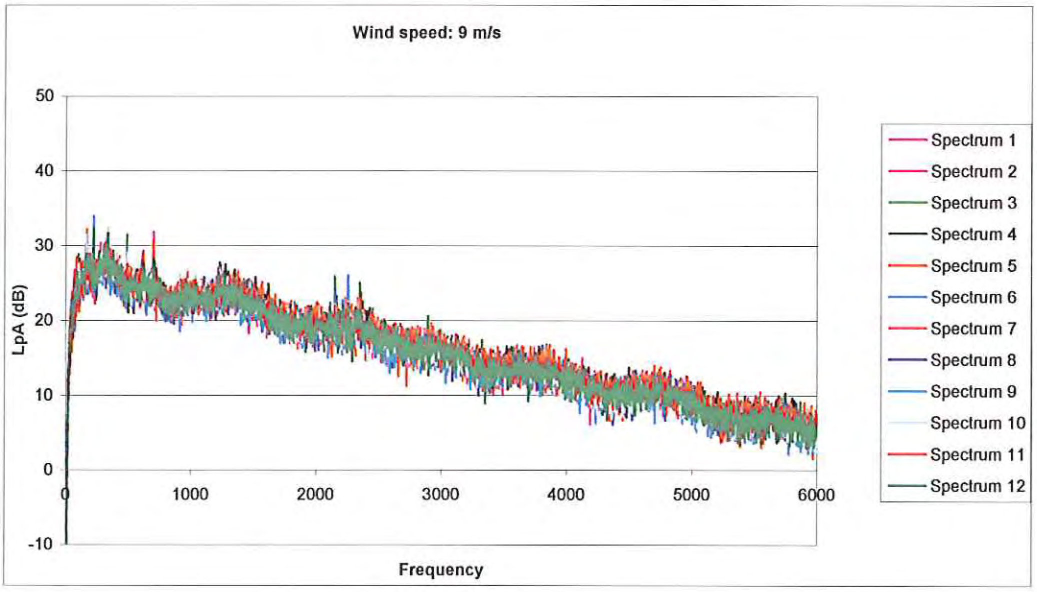
Graph Sheet 7: Tonality analysis at 8 m/s

Linespacing (analysis bandwidth)	2,0 Hz	Vestas V100											
		Wind speed:					8 m/s						
Spectrum no	1	2	3	4	5	6	7	8	9	10	11	12	Avg
Frequency/*Hz*	223	223	223	223	223	223	223	223	223	223	223	223	
Lp,tone/*dB re 20 uPa*	30,0	30,5	30,4		31,3	30,4							
Critical bandwidth/*dB re 20 uPa*	103,6	103,6	103,6	103,6	103,6	103,6	103,6	103,6	103,6	103,6	103,6	103,6	
Lower frequency/*dB re 20 uPa*	171	171	171	171	171	171	171	171	171	171	171	171	
Upper frequency/*dB re 20 uPa*	275	275	275	275	275	275	275	275	275	275	275	275	
Lp,noise,avg/*dB re 20 uPa*	25,4	26,0	26,0		25,5	26,1							
10*log(Critical bandwidth/Analysis bandwidth)	15,4	15,4	15,4	15,4	15,4	15,4	15,4	15,4	15,4	15,4	15,4	15,4	
Lp,critical band/*dB re 20 uPa*	40,8	41,4	41,4		40,9	41,5							
♦Ltn	**-10,8**	**-10,9**	**-11,0**	**-15,4**	**-9,6**	**-11,1**	**-15,4**	**-15,4**	**-15,4**	**-15,4**	**-15,4**	**-15,4**	**-12,8**
♦La	**-8,7**	**-8,8**	**-8,9**	**-13,3**	**-7,5**	**-9,0**	**-13,3**	**-13,3**	**-13,3**	**-13,3**	**-13,3**	**-13,3**	**-10,7**



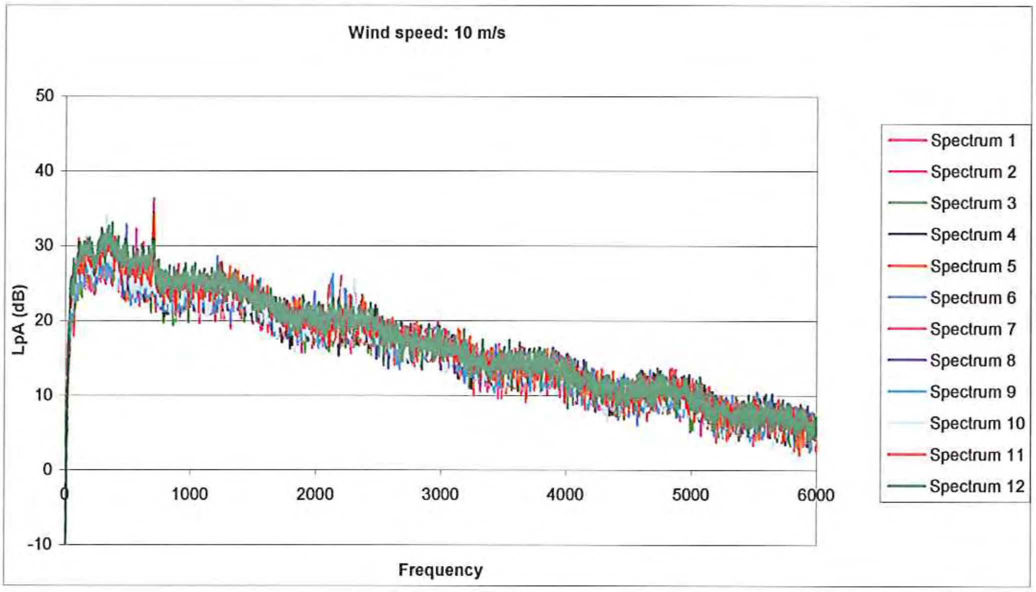
Graph Sheet 8: Tonality analysis at 9 m/s

			Vestas V100										
Linespacing (analysis bandwidth)	2,0 Hz		Wind speed:				9 m/s						
Spectrum no	1	2	3	4	5	6	7	8	9	10	11	12	Avg
Frequency/Hz	223	223	223	223	223	223	223	223	223	223	223	223	
Lp,tone/dB re 20 uPa		31,4	31,9	31,1		32,3	30,7		31,6				
Critical bandwidth/dB re 20 uPa	103,6	103,6	103,6	103,6	103,6	103,6	103,6	103,6	103,6	103,6	103,6	103,6	
Lower frequency/dB re 20 uPa	171	171	171	171	171	171	171	171	171	171	171	171	
Upper frequency/dB re 20 uPa	275	275	275	275	275	275	275	275	275	275	275	275	
Lp,noise,avg/dB re 20 uPa		26,9	26,9	26,7		26,4	26,3		26,5				
10*log(Critical bandwidth/Analysis bandwidth)	15,4	15,4	15,4	15,4	15,4	15,4	15,4	15,4	15,4	15,4	15,4	15,4	
Lp,critical band/dB re 20 uPa		42,3	42,3	42,1		41,8	41,7		41,9				
♦Ltn	-15,4	-10,9	-10,4	-11,0	-15,4	-9,5	-11,0	-15,4	-10,3	-15,4	-15,4	-15,4	-12,3
♦La	-13,3	-8,8	-8,3	-8,9	-13,3	-7,4	-8,9	-13,3	-8,2	-13,3	-13,3	-13,3	-10,2



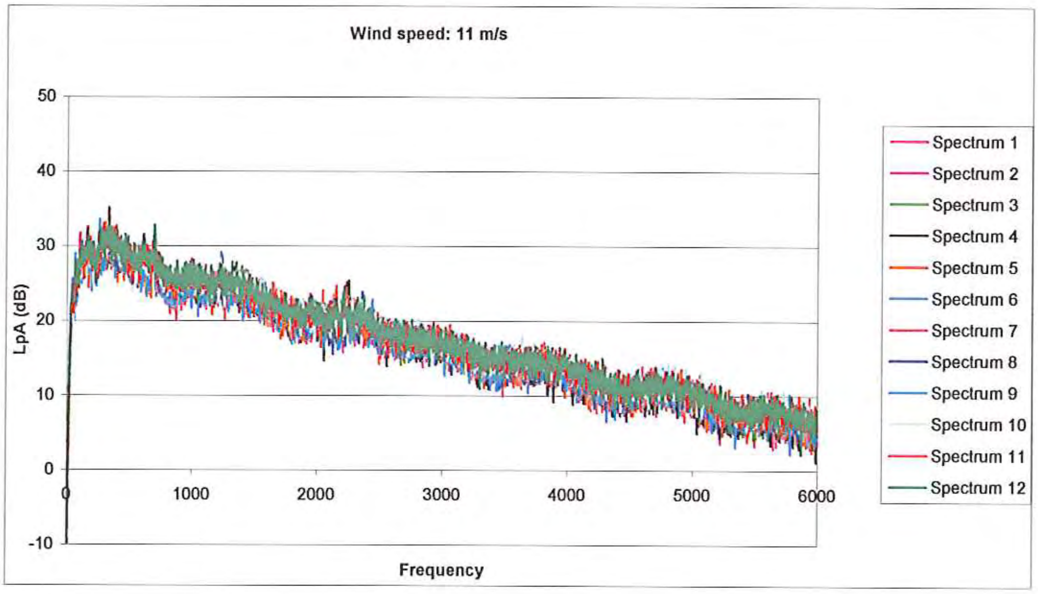
Graph Sheet 9: Tonality analysis at 10 m/s

Linespacing (analysis bandwidth)	2,0 Hz		Vestas V100 Wind speed: 10 m/s										
Spectrum no	1	2	3	4	5	6	7	8	9	10	11	12	Avg
Frequency/*Hz*	706	707	705	703	703	709	706	706	706	706	709	706	
Lp,tone/*dB re 20 uPa*		37,7	39,3	37,2	34,0	31,6					35,6		
Critical bandwidth/*dB re 20 uPa*	133,1	133,2	133,0	132,8	132,8	133,3	133,1	133,1	133,1	133,1	133,3	133,1	
Lower frequency/*dB re 20 uPa*	639	640	639	637	637	642	639	639	639	639	642	639	
Upper frequency/*dB re 20 uPa*	773	774	771	769	769	776	773	773	773	773	776	773	
Lp,noise,avg/*dB re 20 uPa*		25,0	24,7	25,0	25,1	25,1					26,5		
10*log(Critical bandwidth/Analysis bandwidth)	16,5	16,5	16,5	16,5	16,5	16,5	16,5	16,5	16,5	16,5	16,5	16,5	
Lp,critical band/*dB re 20 uPa*		41,5	41,2	41,5	41,6	41,6					43,0		
♦Ltn	-16,5	-3,8	-1,9	-4,3	-7,6	-10,0	-16,5	-16,5	-16,5	-16,5	-7,4	-16,5	-7,7
♦La	-13,9	-1,3	0,6	-1,8	-5,1	-7,5	-13,9	-13,9	-13,9	-13,9	-4,9	-13,9	-5,2



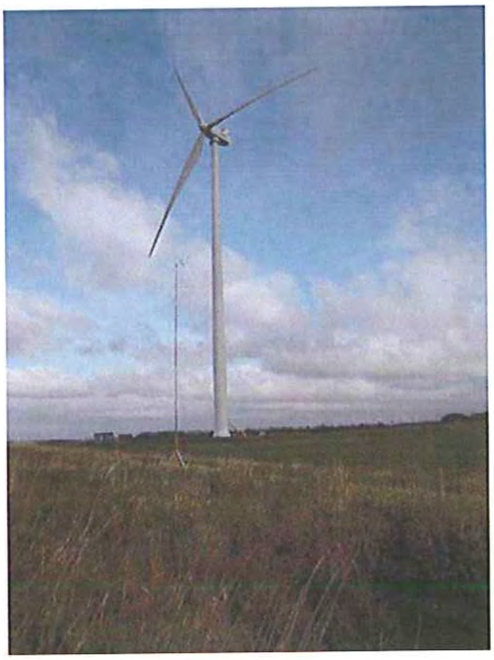
Graph Sheet 10: Tonality analysis at 11 m/s

Linespacing (analysis bandwidth)	2,0 Hz		Vestas V100 Wind speed:					11 m/s					
Spectrum no	1	2	3	4	5	6	7	8	9	10	11	12	Avg
Frequency/*Hz*	533	533	531	533	533	535	533	533	533	533	533	533	
Lp,tone/*dB re 20 uPa*			40,1		40,2	41,1		36,4					
Critical bandwidth/*dB re 20 uPa*	119,5	119,5	119,4	119,5	119,5	119,6	119,5	119,5	119,5	119,5	119,5	119,5	
Lower frequency/*dB re 20 uPa*	473	473	471	473	473	475	473	473	473	473	473	473	
Upper frequency/*dB re 20 uPa*	593	593	591	593	593	595	593	593	593	593	593	593	
Lp,noise,avg/*dB re 20 uPa*			31,7		31,9	32,1		31,9					
10*log(Critical bandwidth/Analysis bandwidth)	16,0	16,0	16,0	16,0	16,0	16,0	16,0	16,0	16,0	16,0	16,0	16,0	
Lp,critical band/*dB re 20 uPa*			47,7		47,9	48,1		47,9					
♦Ltn	-16,0	-16,0	-7,6	-16,0	-7,7	-7,0	-16,0	-11,5	-16,0	-16,0	-16,0	-16,0	-11,7
♦La	-13,7	-13,7	-5,3	-13,7	-5,4	-4,7	-13,7	-9,2	-13,7	-13,7	-13,7	-13,7	-9,3



Annex 1: Photo from the site 25th September 2010

Annex 2: Photo from the site - 14th and 15th October 2010



Annex 3: Wind turbine specifications

– **Wind turbine details:**	
• manufacturer;	Vestas Wind Systems A/S
• model number	V100-1.8MW VCS
• serial number	36612
– **Operating details:**	
• vertical or horizontal axis wind turbine	Horizontal
• upwind or downwind rotor	Upwind
• hub height	106 m
• horizontal distance from rotor centre to tower axis	5 m
• diameter of rotor	100 m
• tower type (lattice or tube)	Cylindrical and/or tapered tubular
• passive stall, active stall, or pitch controlled turbine	Pitch control
• constant or variable speed	Variable speed
• rated power output	1800 MW
• control software version	OptiSpeed
– **Rotor details:**	
• rotor control devices	Hydraulic
• presence of vortex generators, stall strips, serrated trailing edges	Vortex Generators
• blade type	Vestas 49.3 m PP
• number of blades	3
– **Gearbox details:**	
• Manufacturer	Winergy
• model number	4828500-0020-2
• fixed-parallel-shaft or planetary gearbox	1 planetary stage + 2 helical stages
• Gear ratio	1:113.1
– **Generator details:**	
• Manufacturer	VND
• Model number	623476 Typ:DVSG 500/4M SP
• Rated RPM	1000 – 1680 rpm -

Annex 4: Power Curve

(Data from air density 1.225 is used)

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12 Appendices

Power Curve, C_t values and Sound Power Levels for Mode 0 to 2 are defined below.

12.1 Mode 0

12.1.1 Mode 0, Power Curve

Mode 0, Power curves														
	Air density kg/m³													
Wind speed [m/s]	1.225	0.95	0.975	1	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	13	13	14	14
3.5	52	34	36	37	39	41	42	44	45	47	48	50	53	55
4	108	79	81	84	87	90	92	95	98	100	103	106	111	114
4.5	177	133	137	141	145	149	153	157	161	165	169	173	181	185
5	256	195	201	206	212	217	223	229	234	240	245	251	262	268
5.5	350	268	275	283	290	298	305	312	320	327	335	342	357	364
6	458	353	362	372	382	391	401	410	420	430	439	449	468	477
6.5	589	452	464	477	489	502	514	527	539	552	564	576	601	614
7	744	573	588	604	620	635	651	666	682	697	713	728	759	774
7.5	916	709	728	747	766	785	804	822	841	860	878	897	934	953
8	1106	861	884	906	929	952	974	996	1018	1040	1062	1084	1128	1150
8.5	1312	1028	1054	1080	1107	1133	1159	1185	1210	1236	1261	1287	1337	1362
9	1510	1206	1235	1265	1295	1324	1352	1380	1408	1436	1461	1486	1532	1554
9.5	1663	1385	1416	1446	1477	1507	1532	1556	1581	1606	1625	1644	1678	1693
10	1749	1551	1575	1600	1625	1649	1666	1683	1699	1716	1727	1738	1757	1764
10.5	1784	1673	1689	1705	1721	1737	1746	1754	1763	1772	1776	1780	1786	1789
11	1796	1749	1756	1764	1771	1779	1782	1785	1788	1791	1793	1794	1796	1797
11.5	1799	1781	1784	1787	1790	1793	1794	1795	1797	1798	1798	1799	1800	1800
12	1800	1793	1795	1796	1797	1798	1799	1799	1799	1800	1800	1800	1800	1800
12.5	1800	1799	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

Annex 5: Instruments

No.	Equipment	Make	Type
17L027	Cup anemometer	Schiltknecht	Vindmaster mkII
02L021	Calibrator	Brüel & Kjær	4231
14L004	Data acquisition card	NI	9233
06L060	½" Microphone	G.R.A.S.	40AE
09L037	Preamplifier	G.R.A.S.	26CF
10L011	Measurement software	DELTA	Wind Turbine 2.0

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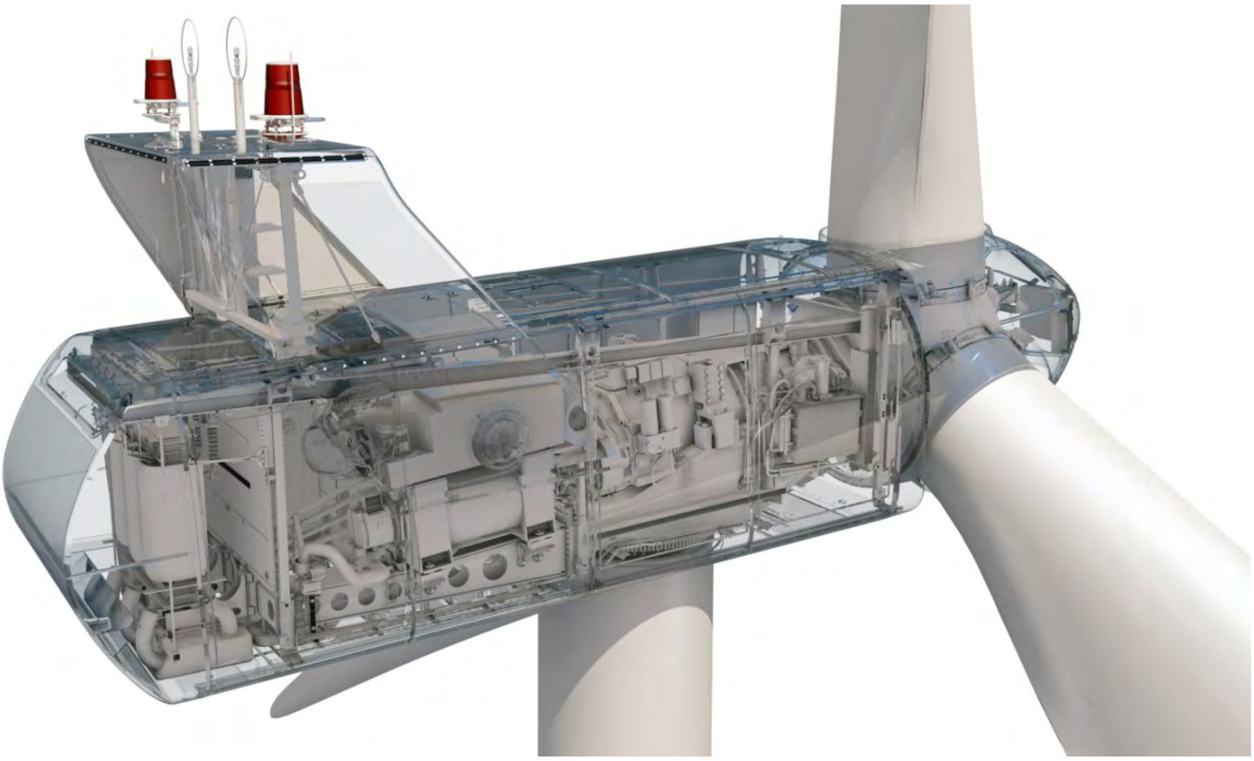
2010-10-06

General Specification

V100–1.8 MW 50 Hz VCS



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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. 39 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 utilizes a microprocessor pitch control system called OptiTip® and the 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 MW turbine is equipped with a 100-meter 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
Chord	3.9 m
Blade Root Outer Diameter	1.88 m

PP Blades	
PCD of Steel Root Inserts	1.80 m
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 4-point contact ball bearings.

Blade Bearing	
Type	2-row 4-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 4-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	Ø125/80 – 760
Number	1 pcs./ blade
Range	-5º to 90º

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 / 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 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	1:113 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 cm^3.

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 fibre glass tube. The coupling is fitted to 3-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 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˚/sec.

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

Tower Structure	
Type Description	Conical tubular
Hub Heights (HH)	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, 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
Base Frame Front	Cast EN-GJS-400-18U-LT / EN 1560
Base Frame Rear	Welded grid structure

Table 2-16: Nacelle base frame 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 Low Temperature (LT) turbine)
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/coolers but are considered as 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 3-way thermostatic valve, which 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 mechanical-driven oil pump and a plate heat exchanger, and the second circuit is equipped with an electrical-driven oil pump and a plate heat exchanger. The water circuit of the two plate heat exchangers are 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
No. 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
No. 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
No. 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 which 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: 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/min (50% glycol)
Water inlet pressure	Max 2.0 bar
Water inlet temperature	Maximum 54ºC
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. The cooler removes the internal losses in the generator and in three fans (two internal and one external). 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:

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 (generated by mechanical and electrical equipment) from the nacelle.

Nacelle Cooling	
Nominal air flow	1.2 m^3/s
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 3-phase asynchronous generator with wound rotor, which 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 exhausts it out through the rear end 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.

Generator	
Type Description	Asynchronous with wound rotor, slip rings and VCS
Rated Power (PN)	1.8 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)	0.90 ind – 0.95 cap
Over Speed Limit acc. to IEC (2 min.)	2900 rpm
Vibration Level	≤ 1.8 mm/s
Weight	Approximately 7500 kg
Generator Bearing - Temperature	2 PT100 sensors
Generator Stator Windings - Temperature	3 PT100 sensors placed at hot spots and 3 as back-up

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 4-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	3x70/70 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 a TN-system, which means the star point is connected to earth.

Transformer	
Type Description	Dry-type cast resin
Primary Voltage	6-35 kV
Rated Apparent 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	50/60 Hz
HV-tappings	± 2 x 2.5% offload
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 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 & 480V)	232 A
Rated Rotor Current (@ rated slip & 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
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 optical-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	3 channel PT100 module	CAN I/O module
CT6050	Blade controller	CAN node
Balluf	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 back up time for the UPS system is proportional to the power consumption. Actual back-up 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 V AC	
Rated Output Voltage	230 V AC	
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 back-up 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 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} **(415V 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 rotating errors.

The turbine is also equipped with a VOG (Vestas Overspeed Guard), which is an independent computer module measuring the rotor RPM, and 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 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. Lightning strikes are considered force majeure, i.e. damage caused by lightning strikes is not warranted by Vestas.

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 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. 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 equipped 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 anchorage points in the tower, nacelle, 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. 29 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
Bedframe	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 7-1: 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 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 7-2: 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 1kV	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

Design Codes – Electrical Equipment	
Rotating Electrical Machines	IEC 34
Dimensions and Output Ratings for Rotating Electrical Machines	IEC 72 & 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. 27.

Design Codes – EMC System	
Designed according to	IEC 61400-1: 2005
Further robustness requirements according to	TPS 901795

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 7-5: 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 1kV 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 climatic 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 needed 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 min. average)	42.5 m/s
Survival Wind Speed (3 sec. 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 acc. 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 acc. 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 not 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 as determined by the sensors and control system of the turbine.

Operational Envelope – Temperature and Wind	
Ambient Temperature Interval (Normal Temperature Turbine)	-20° to +40° C
Cut-in (10 min. average)	3 m/s
Cut-out (100 sec. exponential average)	20 m/s
Re-cut in (100 sec. 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}	50 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 sec.	440 V	759 V
Voltage above 115% of nominal for 2 sec.	460 V	794 V
Voltage above 120% of nominal for 0.08 sec.	480 V	828 V
Voltage above 125% of nominal for 0.005 sec	500 V	863 V
Voltage below 90% of nominal for 60 sec.	360 V	621 V
Voltage below 85% of nominal for 11 sec.	340 V	586 V
Frequency is above [Hz] for 0.2 sec.	53 Hz	
Frequency is below [Hz] for 0.2 sec.	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 as illustrated in Figure 9-1, p. 31.

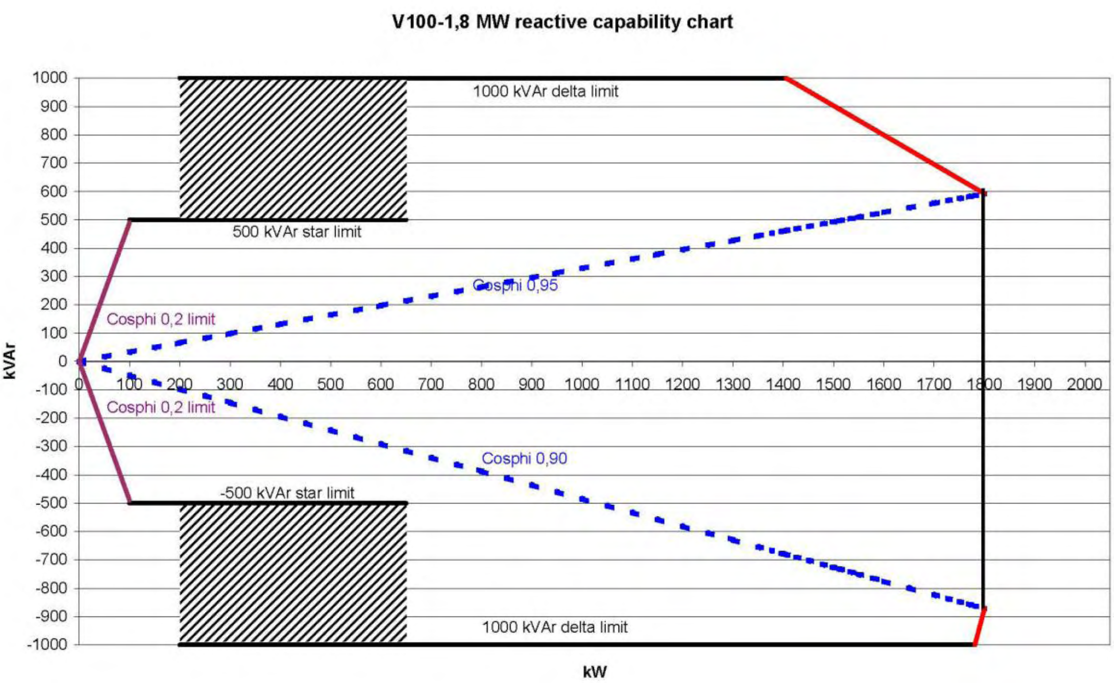


Figure 9-1: Reactive power capability.

The above chart applies at the low voltage side of the HV transformer. Reactive power is produced by the rotor converter; 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 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 9-2, p. 32.

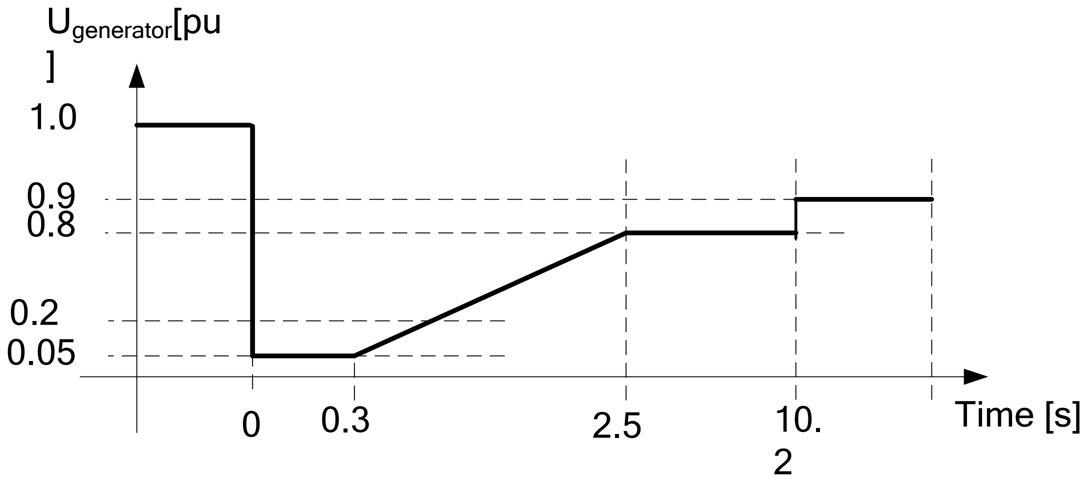


Figure 9-2: Low voltage tolerance curve for symmetrical and asymmetrical faults.

For grid disturbances outside the protection curve in Figure 9-3, p. 33, the turbine will be disconnected from the grid.

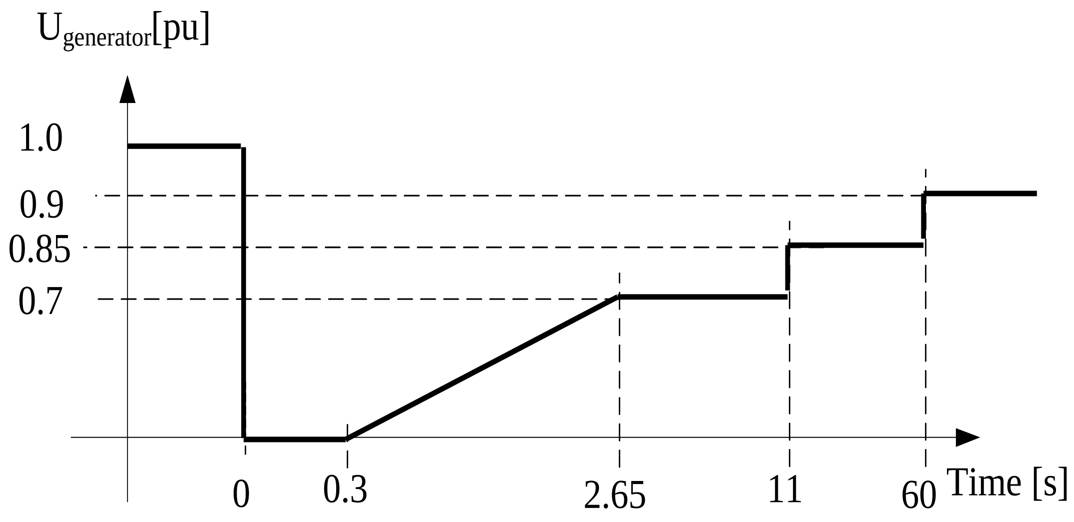


Figure 9-3: Default low voltage protection settings for symmetrical and asymmetrical faults.

Power Recovery Time	
Power recovery to 90% of pre-fault level	Max 1.0 sec

9.6 Performance – Reactive Current Contribution

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

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 (Figure 9-4, p. 34).

The default value gives a reactive current part of 1 pu of the rated turbine current at the generator terminals. Figure 9-4, p. 34 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.

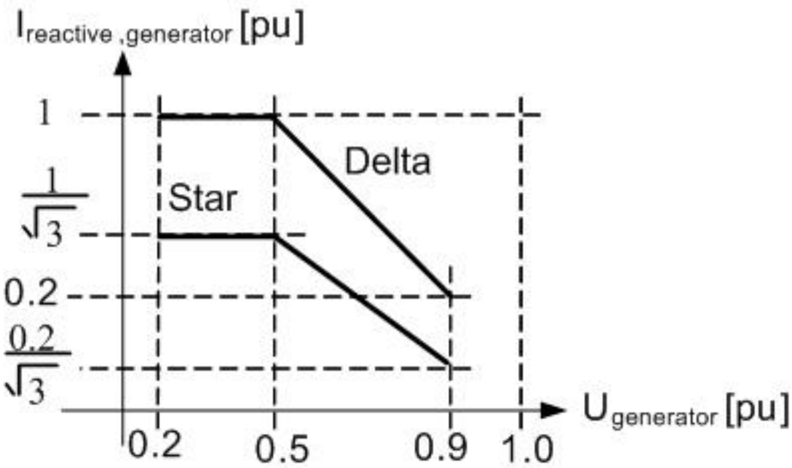


Figure 9-4: Reactive current contribution in star and delta drawn for 100% reactive current contribution.

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 which 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 magnetization 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-phase or phase-ground RMS per unit voltage measured and 'u_{pu_low}' as the lowest phase-phase or phase-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 6 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/sec
Reactive Power	2.5 pu/sec

To protect the turbine active power cannot be controlled to values below the curve in Figure 9-5, p. 35.

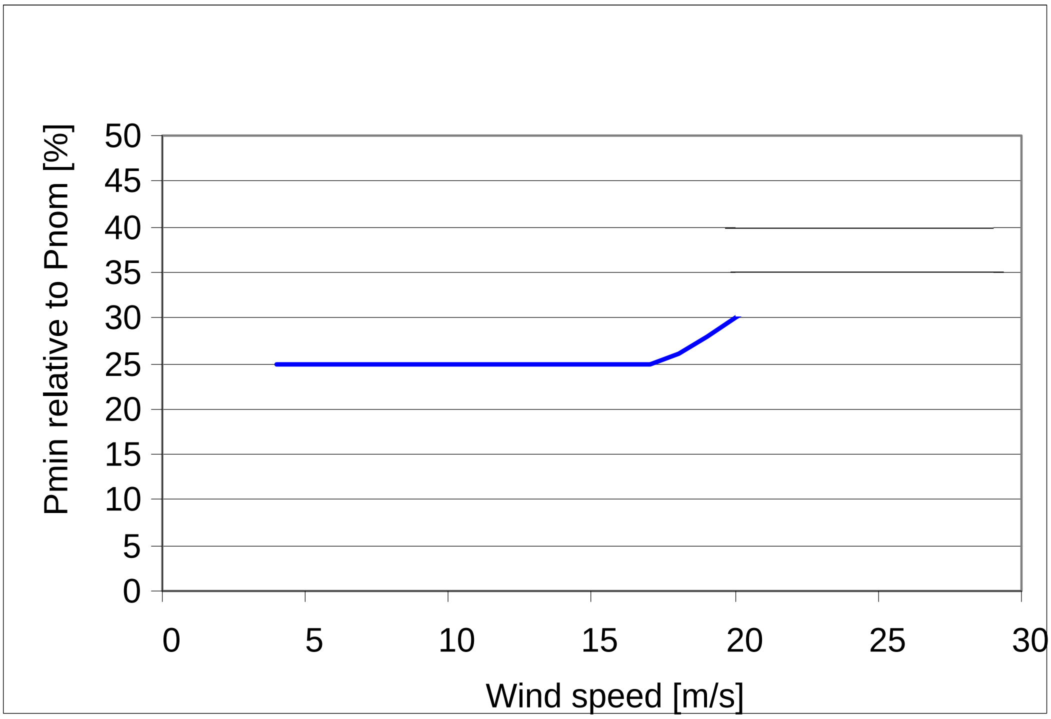


Figure 9-5: Minimum active power output dependant of wind speed.

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).

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

9.11 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 (std) **3 x 6 kW (LT)**	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	Maximum 3.9 kW

Table 9-6: Own consumption data.

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

See appendix section 12.1 Mode 0, p. 40, 12.2 Mode 1, p. 44 and 12.3 Mode 2, p. 48 for power curve, C_t values and noise level.

Conditions for Power Curve, C_t Values (at Hub Height)	
Wind Shear	0.10 - 0.16 (10 min. average)
Turbulence Intensity	8 - 12% (10 min. 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 9-7: Conditions for power curve, C_t values.

10 Drawings

10.1 Structural Design – Illustration of Outer Dimensions

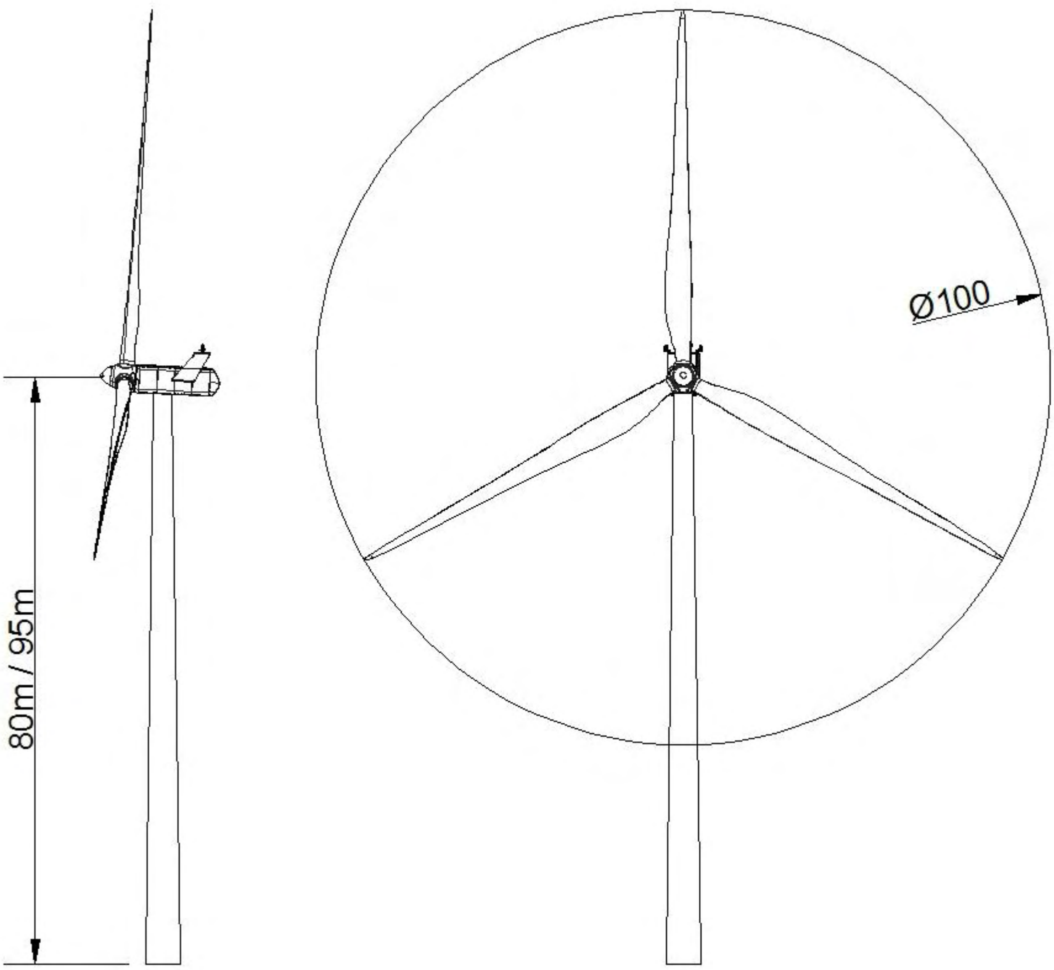


Figure 10-1: Illustration of outer dimensions – structure.

10.2 Structural Design – Side View Drawing

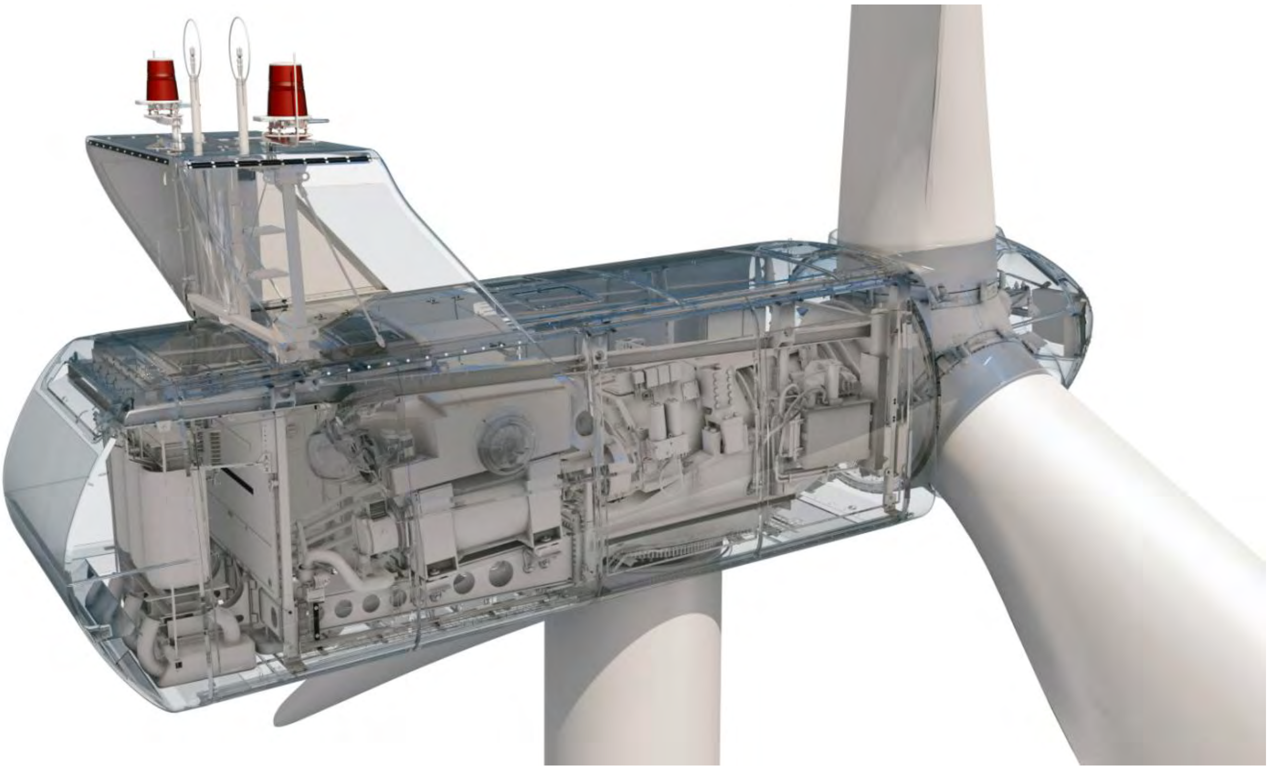


Figure 10-2: Side view drawing.

11 General Reservations, Notes and Disclaimers

- These general specifications 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.
- Periodic operational disturbances and generator power de-rating may be caused by combination of high winds, low voltage or high temperature.
- 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.
- Lightning strikes are considered force majeure, i.e. damage caused by lightning strikes is not warranted by Vestas.
- For the avoidance of doubt, 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 Mode 0 to 2 are defined below.

12.1 Mode 0

12.1.1 Mode 0, Power Curve

Mode 0, Power curves														
	Air density kg/m^3													
Wind speed [m/s]	**1.225**	**0.95**	**0.975**	**1**	**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	13	13	14	14
3.5	**52**	34	36	37	39	41	42	44	45	47	48	50	53	55
4	**108**	79	81	84	87	90	92	95	98	100	103	106	111	114
4.5	**177**	133	137	141	145	149	153	157	161	165	169	173	181	185
5	**256**	195	201	206	212	217	223	229	234	240	245	251	262	268
5.5	**350**	268	275	283	290	298	305	312	320	327	335	342	357	364
6	**458**	353	362	372	382	391	401	410	420	430	439	449	468	477
6.5	**589**	452	464	477	489	502	514	527	539	552	564	576	601	614
7	**744**	573	588	604	620	635	651	666	682	697	713	728	759	774
7.5	**916**	709	728	747	766	785	804	822	841	860	878	897	934	953
8	**1106**	861	884	906	929	952	974	996	1018	1040	1062	1084	1128	1150
8.5	**1312**	1028	1054	1080	1107	1133	1159	1185	1210	1236	1261	1287	1337	1362
9	**1510**	1206	1235	1265	1295	1324	1352	1380	1408	1436	1461	1486	1532	1554
9.5	**1663**	1385	1416	1446	1477	1507	1532	1556	1581	1606	1625	1644	1678	1693
10	**1749**	1551	1575	1600	1625	1649	1666	1683	1699	1716	1727	1738	1757	1764
10.5	**1784**	1673	1689	1705	1721	1737	1746	1754	1763	1772	1776	1780	1786	1789
11	**1796**	1749	1756	1764	1771	1779	1782	1785	1788	1791	1793	1794	1796	1797
11.5	**1799**	1781	1784	1787	1790	1793	1794	1795	1797	1798	1798	1799	1800	1800
12	**1800**	1793	1795	1796	1797	1798	1799	1799	1799	1800	1800	1800	1800	1800
12.5	**1800**	1799	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

Mode 0, Power curves														
	Air density kg/m^3													
Wind speed [m/s]	**1.225**	**0.95**	**0.975**	**1**	**1.025**	**1.05**	**1.075**	**1.1**	**1.125**	**1.15**	**1.175**	**1.2**	**1.25**	**1.275**
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: Mode 0, power curve.

12.1.2 Mode 0, C_t Values

Mode 0, C_t values														
	Air density kg/m^3													
Wind speed [m/s]	**1.225**	**0.95**	**0.975**	**1**	**1.025**	**1.05**	**1.075**	**1.1**	**1.125**	**1.15**	**1.175**	**1.2**	**1.25**	**1.275**
3	**0.868**	0.868	0.868	0.868	0.868	0.868	0.868	0.868	0.868	0.868	0.868	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**	0.882	0.882	0.882	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	**0.826**	0.826	0.826	0.826	0.826	0.826	0.826	0.826	0.826	0.826	0.826	0.826	0.826	0.826
5.5	**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
6	**0.803**	0.803	0.803	0.803	0.803	0.802	0.803	0.803	0.803	0.803	0.803	0.803	0.803	0.803
6.5	**0.819**	0.819	0.819	0.819	0.819	0.819	0.819	0.819	0.819	0.819	0.819	0.819	0.819	0.819
7	**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
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	0.805	0.805
8	**0.792**	0.800	0.800	0.799	0.799	0.798	0.797	0.797	0.796	0.795	0.794	0.793	0.791	0.790
8.5	**0.762**	0.783	0.782	0.780	0.778	0.776	0.774	0.773	0.771	0.769	0.766	0.764	0.759	0.757
9	**0.707**	0.751	0.748	0.745	0.742	0.739	0.735	0.731	0.727	0.723	0.718	0.713	0.701	0.695
9.5	**0.629**	0.704	0.699	0.694	0.688	0.683	0.676	0.669	0.662	0.654	0.646	0.637	0.620	0.611
10	**0.541**	0.648	0.639	0.630	0.622	0.613	0.603	0.593	0.583	0.573	0.562	0.551	0.530	0.520
10.5	**0.457**	0.580	0.569	0.558	0.546	0.535	0.524	0.512	0.501	0.489	0.479	0.468	0.447	0.437
11	**0.387**	0.509	0.496	0.484	0.471	0.459	0.448	0.437	0.426	0.415	0.406	0.396	0.379	0.370
11.5	**0.332**	0.439	0.427	0.416	0.404	0.393	0.383	0.374	0.365	0.355	0.347	0.339	0.325	0.318
12	**0.287**	0.378	0.368	0.359	0.349	0.339	0.331	0.323	0.315	0.307	0.300	0.294	0.281	0.275

Mode 0, C_t values														
	Air density kg/m^3													
Wind speed [m/s]	**1.225**	**0.95**	**0.975**	**1**	**1.025**	**1.05**	**1.075**	**1.1**	**1.125**	**1.15**	**1.175**	**1.2**	**1.25**	**1.275**
12.5	**0.251**	0.329	0.321	0.312	0.304	0.295	0.288	0.282	0.275	0.268	0.262	0.257	0.246	0.241
13	**0.221**	0.288	0.281	0.274	0.266	0.259	0.253	0.247	0.242	0.236	0.231	0.226	0.217	0.213
13.5	**0.197**	0.255	0.248	0.242	0.236	0.230	0.225	0.220	0.214	0.209	0.205	0.201	0.193	0.189
14	**0.176**	0.227	0.221	0.216	0.210	0.205	0.200	0.196	0.191	0.187	0.183	0.179	0.172	0.169
14.5	**0.158**	0.203	0.198	0.193	0.188	0.183	0.180	0.176	0.172	0.168	0.164	0.161	0.155	0.152
15	**0.142**	0.182	0.178	0.174	0.169	0.165	0.161	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	0.149	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**	0.136	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	0.113	0.111	0.109	0.107	0.104	0.102	0.100	0.097	0.095
17.5	**0.091**	0.114	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
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	0.064	0.061	0.060

Table 12-2: Mode 0, C_t values.

12.1.3 Mode 0, Sound Power Levels

Sound Power Level at Hub Height, Mode 0		
Conditions for Sound Power Level	**Verification standard: IEC 61400-11 Ed. 2.** **Wind shear 0.15.** **Max turbulence at 10 meter 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 hh [m/sec]	94.0 4.2	94.1 4.3
LwA @ 4 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	96.2 5.6	96.6 5.7
LwA @ 5 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	100.1 7.0	100.7 7.2
LwA @ 6 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	103.9 8.4	104.4 8.6
LwA @ 7 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	105.0 9.8	105.0 10.0
LwA @ 8 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	105.0 11.2	105.0 11.5
LwA @ 9 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	105.0 12.6	105.0 12.9
LwA @ 10 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	105.0 13.9	105.0 14.3
LwA @ 11 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	105.0 15.3	105.0 15.8
LwA @ 12 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	105.0 16.7	105.0 17.2
LwA @ 13 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	105.0 18.1	105.0 18.6

Table 12-3: Sound power level at hub height: Mode 0.

12.2 Mode 1

12.2.1 Mode 1, Power Curves

Mode 1, Power curves														
	Air density kg/m^3													
Wind speed [m/s]	**1.225**	**0.95**	**0.975**	**1**	**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	13	13	14	14
3.5	**52**	34	36	37	39	41	42	44	45	47	48	50	53	55
4	**108**	78	81	84	87	89	92	95	98	100	103	106	111	114
4.5	**174**	131	135	139	143	147	151	155	159	163	167	170	178	182
5	**250**	190	195	201	206	212	217	223	228	233	239	244	255	261
5.5	**338**	259	266	273	280	288	295	302	309	317	324	331	345	353
6	**445**	342	351	361	370	379	389	398	407	417	426	435	454	463
6.5	**582**	447	459	471	484	496	508	521	533	546	558	570	595	607
7	**736**	567	583	598	613	629	644	660	675	691	706	721	751	767
7.5	**907**	702	721	740	759	777	796	814	833	852	870	889	926	944
8	**1099**	853	876	898	921	943	965	988	1010	1032	1054	1076	1121	1143
8.5	**1307**	1020	1047	1073	1099	1126	1152	1178	1204	1230	1255	1281	1332	1357
9	**1509**	1199	1229	1259	1289	1319	1347	1376	1405	1433	1458	1483	1531	1554
9.5	**1664**	1382	1413	1444	1475	1506	1531	1556	1581	1606	1625	1644	1678	1693
10	**1748**	1549	1574	1599	1624	1650	1666	1683	1700	1717	1727	1738	1755	1762
10.5	**1783**	1672	1688	1705	1721	1738	1746	1755	1763	1772	1776	1779	1785	1787
11	**1796**	1750	1757	1765	1772	1780	1783	1786	1789	1792	1793	1794	1796	1797
11.5	**1799**	1781	1784	1787	1790	1793	1795	1796	1797	1798	1798	1799	1799	1800
12	**1800**	1794	1795	1796	1797	1799	1799	1799	1800	1800	1800	1800	1800	1800
12.5	**1800**	1799	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

Mode 1, Power curves														
	Air density kg/m^3													
Wind speed [m/s]	**1.225**	**0.95**	**0.975**	**1**	**1.025**	**1.05**	**1.075**	**1.1**	**1.125**	**1.15**	**1.175**	**1.2**	**1.25**	**1.275**
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: Mode 1, power curve.

12.2.2 Mode 1, C_t Values

Mode 1, C_t values														
	Air density kg/m^3													
Wind speed [m/s]	**1.225**	**0.95**	**0.975**	**1**	**1.025**	**1.05**	**1.075**	**1.1**	**1.125**	**1.15**	**1.175**	**1.2**	**1.25**	**1.275**
3	**0.868**	0.868	0.868	0.868	0.869	0.869	0.869	0.869	0.868	0.868	0.868	0.868	0.868	0.868
3.5	**0.883**	0.883	0.883	0.883	0.883	0.883	0.883	0.883	0.883	0.883	0.883	0.883	0.883	0.883
4	**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
4.5	**0.792**	0.792	0.792	0.792	0.792	0.792	0.792	0.792	0.792	0.792	0.792	0.792	0.792	0.792
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	0.717	0.717	0.717	0.717	0.717
6	**0.713**	0.713	0.713	0.713	0.713	0.713	0.713	0.713	0.713	0.713	0.713	0.713	0.713	0.713
6.5	**0.763**	0.763	0.763	0.763	0.763	0.763	0.763	0.763	0.763	0.763	0.763	0.763	0.763	0.763
7	**0.757**	0.757	0.757	0.757	0.757	0.757	0.757	0.757	0.757	0.756	0.757	0.757	0.757	0.757
7.5	**0.753**	0.753	0.753	0.753	0.753	0.753	0.753	0.753	0.753	0.753	0.753	0.753	0.753	0.753
8	**0.749**	0.749	0.749	0.749	0.749	0.749	0.749	0.749	0.749	0.749	0.749	0.749	0.749	0.749
8.5	**0.733**	0.743	0.743	0.742	0.741	0.740	0.739	0.738	0.737	0.736	0.735	0.734	0.731	0.730
9	**0.694**	0.725	0.723	0.721	0.719	0.717	0.715	0.712	0.710	0.707	0.703	0.698	0.689	0.683
9.5	**0.625**	0.693	0.689	0.684	0.680	0.676	0.669	0.663	0.656	0.650	0.641	0.633	0.616	0.606
10	**0.539**	0.644	0.636	0.627	0.619	0.611	0.601	0.591	0.581	0.571	0.560	0.549	0.528	0.517
10.5	**0.456**	0.579	0.568	0.557	0.546	0.535	0.523	0.512	0.500	0.489	0.478	0.467	0.446	0.436
11	**0.387**	0.509	0.497	0.484	0.472	0.459	0.448	0.437	0.426	0.415	0.406	0.396	0.378	0.370
11.5	**0.331**	0.439	0.427	0.416	0.404	0.393	0.383	0.374	0.365	0.355	0.347	0.339	0.324	0.317
12	**0.287**	0.378	0.369	0.359	0.349	0.339	0.331	0.323	0.315	0.307	0.300	0.294	0.281	0.275
12.5	**0.251**	0.329	0.321	0.312	0.304	0.295	0.288	0.282	0.275	0.268	0.262	0.257	0.246	0.241
13	**0.221**	0.288	0.281	0.274	0.266	0.259	0.253	0.247	0.242	0.236	0.231	0.226	0.217	0.213
13.5	**0.197**	0.255	0.248	0.242	0.236	0.230	0.225	0.220	0.214	0.209	0.205	0.201	0.193	0.189
14	**0.176**	0.227	0.221	0.216	0.210	0.205	0.200	0.196	0.191	0.187	0.183	0.179	0.172	0.169

Mode 1, C_t values														
	Air density kg/m^3													
Wind speed [m/s]	1.225	0.95	0.975	1	1.025	1.05	1.075	1.1	1.125	1.15	1.175	1.2	1.25	1.275
14.5	**0.158**	0.203	0.198	0.193	0.188	0.183	0.180	0.176	0.172	0.168	0.164	0.161	0.155	0.152
15	**0.142**	0.182	0.178	0.174	0.169	0.165	0.161	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	0.149	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**	0.136	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	0.113	0.111	0.109	0.107	0.104	0.102	0.100	0.097	0.095
17.5	**0.091**	0.114	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
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	0.064	0.061	0.060

Table 12-5: Mode 1, C_t values.

12.2.3 Mode 1, Sound Power Levels

Sound Power Level at Hub Height, Mode 1		
Conditions for Sound Power Level	**Verification standard: IEC 61400-11 Ed. 2.** **Wind shear 0.15** **Max turbulence at 10 meter 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 hh [m/sec]	94.0 4.2	94.0 4.3
LwA @ 4 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	95.4 5.6	95.6 5.7
LwA @ 5 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	99.1 7.0	99.7 7.2
LwA @ 6 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	102.9 8.4	103.4 8.6
LwA @ 7 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	105.0 9.8	105.0 10.0
LwA @ 8 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	105.0 11.2	105.0 11.5
LwA @ 9 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	105.0 12.6	105.0 12.9
LwA @ 10 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	105.0 13.9	105.0 14.3
LwA @ 11 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	105.0 15.3	105.0 15.8
LwA @ 12 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	105.0 16.7	105.0 17.2
LwA @ 13 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	105.0 18.1	105.0 18.6

Table 12-6: Sound power level at hub height: Mode 1.

12.3 Mode 2

12.3.1 Mode 2, Power Curves

Mode 2, Power curves														
	Air density kg/m³													
Wind speed [m/s]	**1.225**	**0.95**	**0.975**	**1**	**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	13	13	14	14
3.5	**52**	34	36	37	39	41	42	44	45	47	48	50	53	55
4	**108**	79	81	84	87	90	92	95	98	100	103	106	111	114
4.5	**177**	133	137	141	145	149	153	157	161	165	169	173	181	185
5	**256**	195	201	206	212	217	223	229	234	240	245	251	262	268
5.5	**349**	268	275	282	290	297	305	312	320	327	335	342	357	364
6	**458**	352	362	372	381	391	401	410	420	429	439	448	467	477
6.5	**589**	452	464	477	489	502	514	527	539	552	564	576	601	614
7	**743**	572	588	604	619	635	650	666	681	697	712	728	758	774
7.5	**913**	706	725	744	763	782	801	820	838	857	875	894	931	950
8	**1091**	848	870	892	914	937	959	981	1002	1024	1047	1069	1113	1135
8.5	**1268**	985	1011	1037	1062	1088	1114	1140	1165	1191	1217	1243	1294	1320
9	**1428**	1109	1138	1167	1196	1225	1255	1284	1313	1342	1371	1399	1455	1483
9.5	**1549**	1209	1240	1272	1304	1336	1367	1399	1430	1461	1490	1519	1574	1599
10	**1629**	1285	1319	1353	1387	1421	1453	1484	1516	1548	1575	1602	1650	1672
10.5	**1686**	1346	1381	1416	1451	1486	1517	1548	1580	1611	1636	1661	1704	1722
11	**1732**	1411	1446	1481	1517	1552	1582	1611	1641	1671	1691	1712	1744	1757
11.5	**1763**	1484	1519	1553	1588	1622	1648	1673	1698	1723	1736	1750	1771	1778
12	**1783**	1572	1603	1633	1663	1693	1710	1727	1743	1760	1767	1775	1786	1789
12.5	**1792**	1659	1680	1702	1723	1744	1753	1763	1772	1782	1785	1789	1794	1795
13	**1796**	1725	1737	1749	1761	1774	1778	1783	1787	1792	1793	1795	1797	1798
13.5	**1800**	1757	1765	1773	1780	1788	1791	1793	1796	1798	1799	1799	1800	1800
14	**1800**	1784	1787	1791	1794	1798	1798	1799	1799	1800	1800	1800	1800	1800
14.5	**1800**	1797	1798	1798	1799	1800	1800	1800	1800	1800	1800	1800	1800	1800
15	**1800**	1797	1798	1798	1799	1799	1800	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

Mode 2, Power curves														
	Air density kg/m^3													
Wind speed [m/s]	**1.225**	**0.95**	**0.975**	**1**	**1.025**	**1.05**	**1.075**	**1.1**	**1.125**	**1.15**	**1.175**	**1.2**	**1.25**	**1.275**
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: Mode 2, power curve.

12.3.2 Mode 2, C_t Values

Mode 2, C_t values														
	Air density kg/m^3													
Wind speed [m/s]	**1.225**	**0.95**	**0.975**	**1**	**1.025**	**1.05**	**1.075**	**1.1**	**1.125**	**1.15**	**1.175**	**1.2**	**1.25**	**1.275**
3	0.868	0.868	0.868	0.868	0.868	0.868	0.868	0.868	0.868	0.868	0.868	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	0.882	0.882	0.882	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	0.825	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	0.805	0.805	0.805	0.805	0.805	0.805	0.805	0.805	0.805	0.805	0.805	0.805	0.805	0.805
6	0.799	0.799	0.799	0.799	0.799	0.799	0.799	0.799	0.799	0.799	0.799	0.799	0.799	0.799
6.5	0.817	0.817	0.817	0.817	0.817	0.817	0.817	0.817	0.817	0.817	0.817	0.817	0.817	0.817
7	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
7.5	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785
8	0.749	0.749	0.749	0.749	0.749	0.748	0.748	0.749	0.749	0.749	0.749	0.749	0.749	0.749
8.5	0.696	0.696	0.696	0.696	0.696	0.696	0.696	0.696	0.696	0.696	0.696	0.696	0.696	0.696
9	0.632	0.632	0.632	0.632	0.632	0.632	0.632	0.632	0.633	0.633	0.632	0.632	0.631	0.630
9.5	0.558	0.563	0.563	0.563	0.563	0.563	0.563	0.562	0.562	0.562	0.561	0.560	0.556	0.553
10	0.486	0.496	0.496	0.496	0.496	0.496	0.496	0.495	0.494	0.493	0.491	0.488	0.482	0.478
10.5	0.421	0.437	0.436	0.436	0.436	0.436	0.434	0.433	0.432	0.430	0.427	0.424	0.417	0.412
11	0.367	0.388	0.387	0.387	0.386	0.386	0.384	0.382	0.380	0.378	0.375	0.371	0.362	0.357
11.5	0.322	0.350	0.349	0.348	0.347	0.346	0.343	0.341	0.338	0.335	0.331	0.326	0.317	0.311
12	0.283	0.322	0.320	0.318	0.316	0.314	0.310	0.306	0.302	0.298	0.293	0.288	0.278	0.272
12.5	0.249	0.297	0.294	0.290	0.287	0.283	0.278	0.274	0.269	0.264	0.259	0.254	0.244	0.240
13	0.221	0.273	0.268	0.263	0.259	0.254	0.249	0.244	0.239	0.234	0.230	0.225	0.216	0.212
13.5	0.197	0.247	0.242	0.237	0.233	0.228	0.223	0.218	0.214	0.209	0.205	0.201	0.193	0.189
14	0.176	0.224	0.219	0.214	0.209	0.204	0.200	0.196	0.191	0.187	0.183	0.179	0.172	0.169

Mode 2, C_t values														
	Air density kg/m^3													
Wind speed [m/s]	**1.225**	**0.95**	**0.975**	**1**	**1.025**	**1.05**	**1.075**	**1.1**	**1.125**	**1.15**	**1.175**	**1.2**	**1.25**	**1.275**
14.5	0.158	0.202	0.198	0.193	0.188	0.183	0.180	0.176	0.172	0.168	0.164	0.161	0.155	0.152
15	0.142	0.182	0.177	0.173	0.169	0.165	0.161	0.158	0.155	0.151	0.148	0.145	0.140	0.137
15.5	0.129	0.164	0.161	0.157	0.153	0.149	0.146	0.143	0.140	0.137	0.134	0.132	0.127	0.124
16	0.117	0.149	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	0.136	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	0.113	0.111	0.109	0.107	0.104	0.102	0.100	0.097	0.095
17.5	0.091	0.114	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
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	0.064	0.061	0.060

Table 12-8: Mode 2, C_t values.

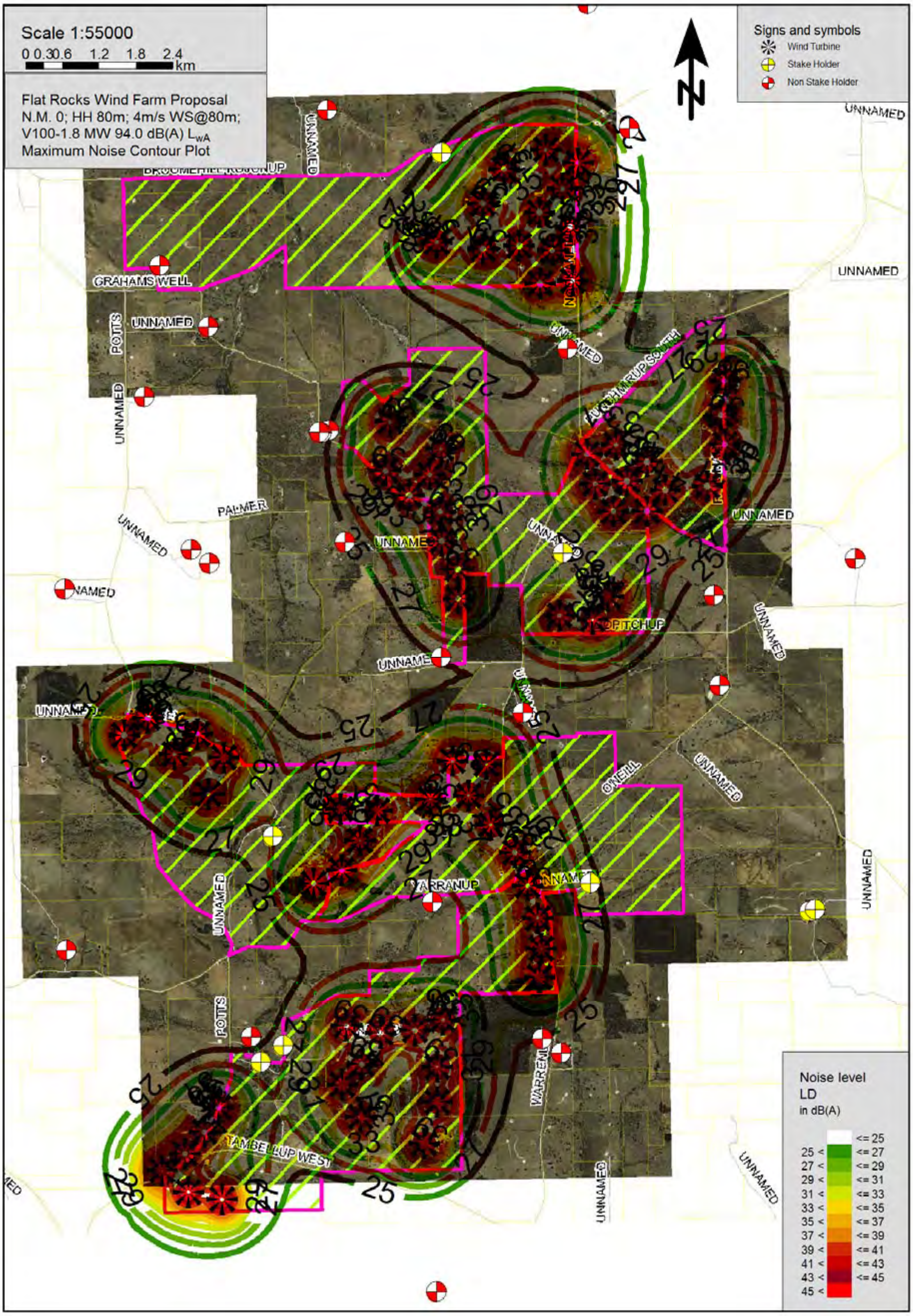
12.3.3 Mode 2, Sound Power Levels

Sound Power Level at Hub Height, Mode 2		
Conditions for Sound Power Level	**Verification standard: IEC 61400-11 Ed. 2.** **Wind shear 0.15** **Max turbulence at 10 meter 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 hh [m/sec]	94.0 4.2	94.1 4.3
LwA @ 4 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	96.2 5.6	96.6 5.7
LwA @ 5 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	100.1 7.0	100.7 7.2
LwA @ 6 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	103.0 8.4	103.0 8.6
LwA @ 7 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	103.0 9.8	103.0 10.0
LwA @ 8 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	103.0 11.2	103.0 11.5
LwA @ 9 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	103.0 12.6	103.0 12.9
LwA @ 10 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	103.0 13.9	103.0 14.3
LwA @ 11 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	103.0 15.3	103.0 15.8
LwA @ 12 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	103.0 16.7	103.0 17.2
LwA @ 13 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	103.0 18.1	103.0 18.6

Table 12-9: Sound power level at hub height: Mode 2.

APPENDIX C

PREDICTED NOISE LEVEL CONTOURS


Scale 1:55000
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km
Flat Rocks Wind Farm Proposal
N.M. 0; HH 80m; 4m/s WS@80m;
V100-1.8 MW 94.0 dB(A) L_{wA}
Maximum Noise Contour Plot
Signs and symbols
Wind Turbine
Stake Holder
Non Stake Holder
N
GRAHAMS WELL
POTTS
PALMER
YARRANUP
TAMBELLUP WEST
WARREN
ONEILL
UNNAMED
Noise level
LD
in dB(A)
<= 25
25 < <= 27
27 < <= 29
29 < <= 31
31 < <= 33
33 < <= 35
35 < <= 37
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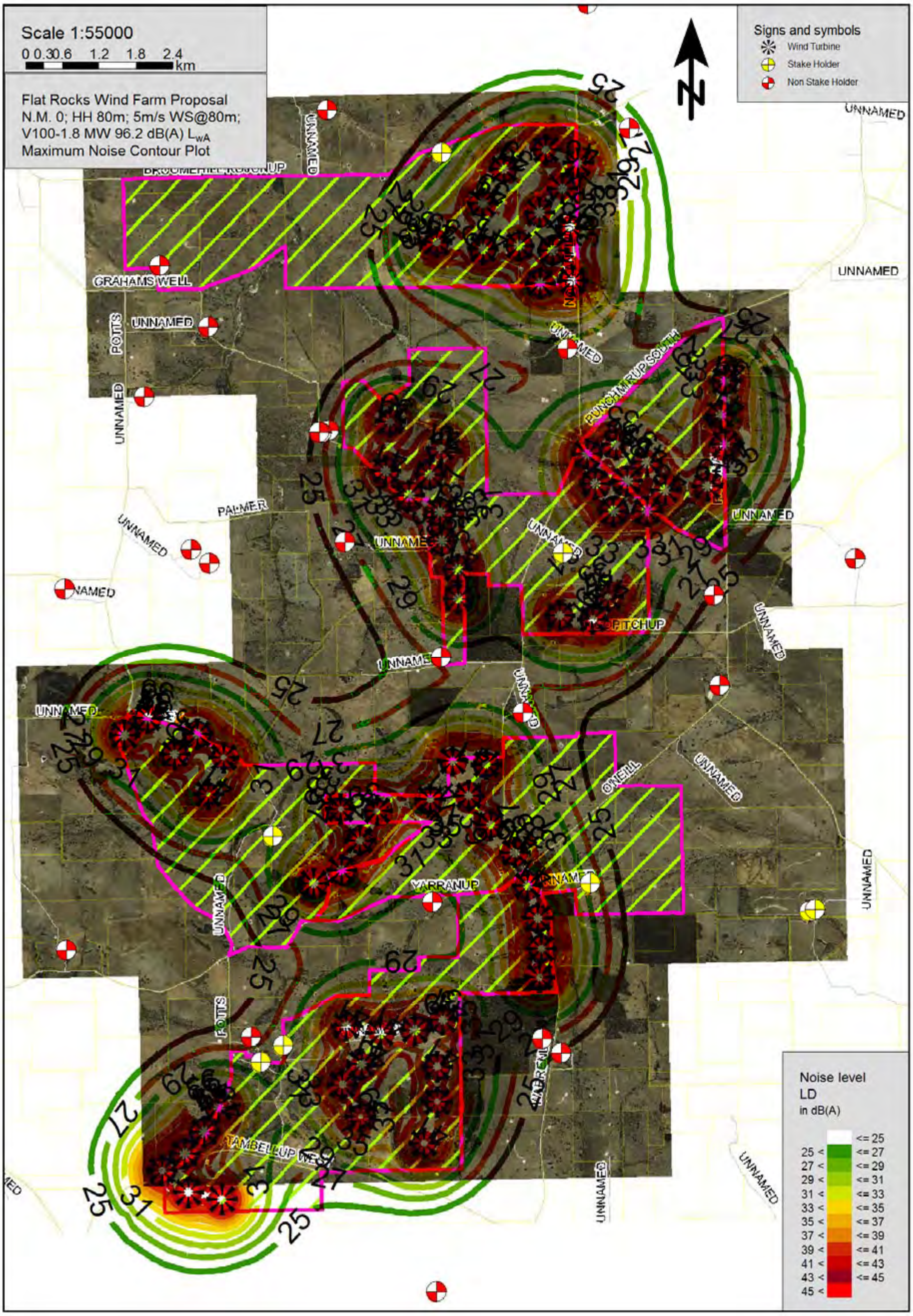
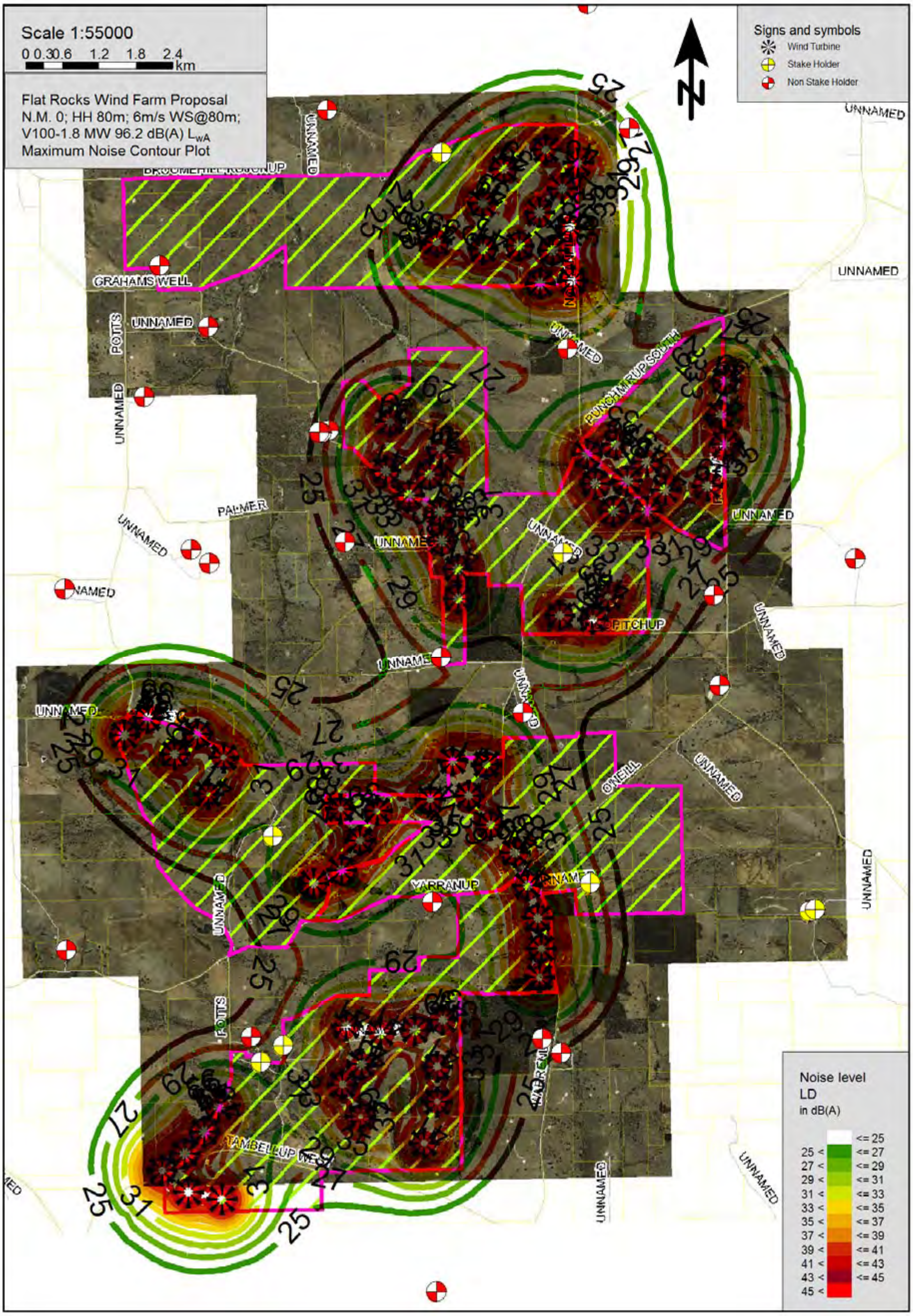
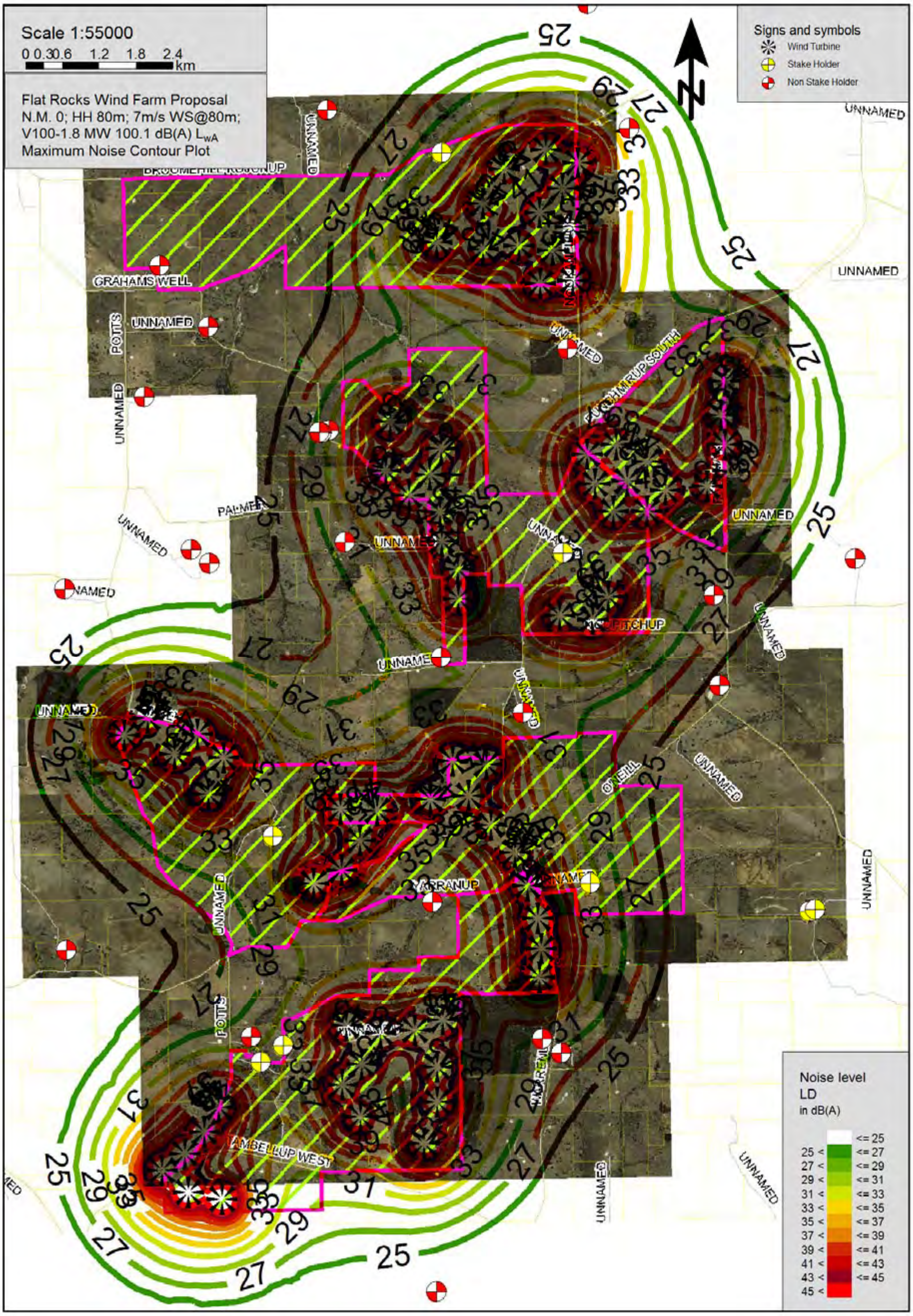
41 < <= 43
43 < <= 45
45 <


Scale 1:55000
0 0.3 0.6 1.2 1.8 2.4 km
Flat Rocks Wind Farm Proposal
N.M. 0; HH 80m; 5m/s WS@80m;
V100-1.8 MW 96.2 dB(A) LwA
Maximum Noise Contour Plot
Signs and symbols
Wind Turbine
Stake Holder
Non Stake Holder
Noise level
LD
in dB(A)
<= 25
25 < <= 27
27 < <= 29
29 < <= 31
31 < <= 33
33 < <= 35
35 < <= 37
37 < <= 39
39 < <= 41
41 < <= 43
43 < <= 45
45 <
GRAHAMS WELL
POTTS
PALMER
PUNCHMIRUP SOUTH
YARRANUP
ONEILL
TAMBELLUP WEST
UNNAMED


Scale 1:55000
0 0.3 0.6 1.2 1.8 2.4
km
Flat Rocks Wind Farm Proposal
N.M. 0; HH 80m; 6m/s WS@80m;
V100-1.8 MW 96.2 dB(A) L_{wA}
Maximum Noise Contour Plot
Signs and symbols
Wind Turbine
Stake Holder
Non Stake Holder
Noise level
LD
in dB(A)
<= 25
25 < <= 27
27 < <= 29
29 < <= 31
31 < <= 33
33 < <= 35
35 < <= 37
37 < <= 39
39 < <= 41
41 < <= 43
43 < <= 45
45 <
GRAHAMS WELL
POTTS
PALMER
YARRANUP
TAMBELLUP WEST
PUNCHMIRUP SOUTH
O'NEILL
UNNAMED

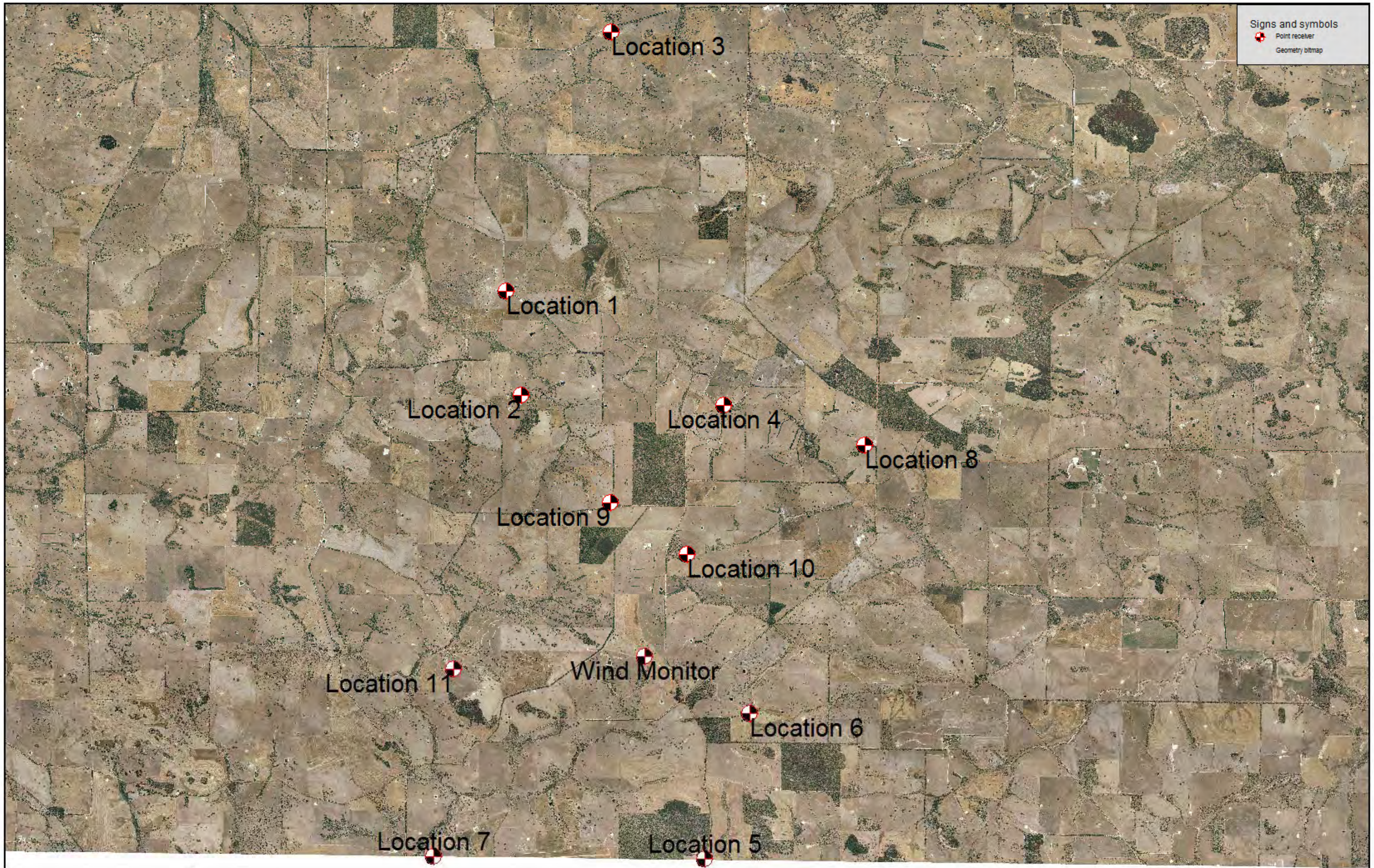

Scale 1:55000
0 0.3 0.6 1.2 1.8 2.4 km
Flat Rocks Wind Farm Proposal
N.M. 0; HH 80m; 7m/s WS@80m;
V100-1.8 MW 100.1 dB(A) LwA
Maximum Noise Contour Plot
Signs and symbols
Wind Turbine
Stake Holder
Non Stake Holder
GRAHAMS WELL
POTTS
UNNAMED
PALMER
ORCHUMUP SOUTH
YARRANUP
AMBELLUP WEST
O'NEILL
Noise level
LD
in dB(A)
<= 25
25 < <= 27
27 < <= 29
29 < <= 31
31 < <= 33
33 < <= 35
35 < <= 37
37 < <= 39
39 < <= 41
41 < <= 43
43 < <= 45
45 <


Scale 1:55000
0 0.3 0.6 1.2 1.8 2.4 km
Flat Rocks Wind Farm Proposal
N.M. 0; HH 80m; 8m/s WS@80m;
V100-1.8 MW 103.9 dB(A) L_{wA}
Maximum Noise Contour Plot
Signs and symbols
Wind Turbine
Stake Holder
Non Stake Holder
Noise level
LD
in dB(A)
<= 25
25 < <= 27
27 < <= 29
29 < <= 31
31 < <= 33
33 < <= 35
35 < <= 37
37 < <= 39
39 < <= 41
41 < <= 43
43 < <= 45
45 <
GRAHAMS WELL
POTTS
UNNAMED
YARRANUP
WARREN


Scale 1:55000
0 0.3 0.6 1.2 1.8 2.4 km
Flat Rocks Wind Farm Proposal
N.M. 0; HH 80m; 9m/s WS@80m;
V100-1.8 MW 105.0 dB(A) L_{wA}
Maximum Noise Contour Plot
Signs and symbols
Wind Turbine
Stake Holder
Non Stake Holder
Noise level
LD
in dB(A)
<= 25
25 < <= 27
27 < <= 29
29 < <= 31
31 < <= 33
33 < <= 35
35 < <= 37
37 < <= 39
39 < <= 41
41 < <= 43
43 < <= 45
45 <
GRAHAMS WELL
POTTS
UNNAMED
YARRANUP
WARREN
PALMER

APPENDIX D

BACKGROUND MONITORING LOCATIONS



Herring Storer Acoustics Job No. 10226-01	Moonies Hill Energy Flat Rocks Wind Farm Background Noise Monitoring	Appendix A Location Map