General Specification

V80 – 1.8 MW
60 Hz
OptiSlip® – Wind Turbine

Item no. 944411.R3 Class 1 (6a)

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1. Introduction

The Vestas V80 - 1.8 MW wind turbine is based on experience gained from several generations of Vestas Wind Turbines. It is designed around a platform closely resembling the Vestas V66 - 1.65 MW Wind Turbine

The Vestas 1.8 MW, with a rotor diameter of 80 m (264 ft.), utilises the Vestas OptiSlip® concept. When compared to regular pitch or stall regulated wind turbines, OptiSlip® technology produces a smoother power output and significant load reductions.

The Vestas OptiTip® feature is also standard on the Vestas V80 - 1.8 MW turbine. OptiTip® continuously optimises blade tip angle for improved power performance and reduced sound emission.

2. Wind Climate

Turbulence describes short-term wind variations or fluctuations. The conditions for which the VESTAS V80-1.8 MW wind turbine was designed are listed below.

IEC Class	Tower height [m]	A-parameter [m/s]	C-parameter [-]	Turbulence at 15 m/s [%]	Reference wind[1)] [m/s]	Reference wind[2)] [m/s]
I	60 – 78	11.3	2.0	18.0	50.0	70.0
II	60 – 78	9.59	2.0	18.0	42.5	59.5

1) 10 min., 50 year wind
2) 5 sec., 50 year wind gust
Wind speed and turbulence are referenced at hub height.

The maximum wind speeds at which the turbine may be operated are listed below.

Model	**Wind gust Max. Acc. [m/s^2]**	**Stop Wind Speed/ Restart Wind Speed [m/s]**
V80-1.8 MW	10	25/20

3. Wind Turbine Description

The Vestas V80 - 1.8 MW is a pitch-regulated, upwind wind turbine with active yaw and a three - blade rotor.

The blades are made of glass fibre reinforced epoxy. Each blade consists of two shells, bonded to a supporting beam. Special steel root inserts connect the blade to the blade bearing. The blade bearing is a 4-point ball bearing bolted to the blade hub.

The main shaft transmits the power to the generator through a combined planetary-helical gearbox. Power is transmitted from the gearbox to the generator via a maintenance-free composite coupling.

The generator is a asynchronous (induction) 4-pole generator with wound rotor and Vestas OptiSlip® technology. Grid connection is accomplished through thyristors that are by-passed after generator cut-in.

The pitch system together with the unique Vestas OptiSlip® generator combine to maintain smooth, nominal power output at higher wind speeds. This power output is hence independent of air temperature and air density. At lower wind speeds, the pitch system and OptiTip® technology optimise the power through the calculated blade pitch angle.

Turbine braking is accomplished by full blade feathering. A secondary fail-safe mechanical brake system is mounted on the High- Speed shaft connecting the gearbox to the generator.

All turbine functions are monitored and controlled by microprocessor-based control units in the nacelle. Blade pitch changes are activated by hydraulics that also supply mechanical brake-system pressure. Each blade is equipped with a hydraulic cylinder enabling the blade to rotate 95°.

Four (4) electrical yaw gear-motors perform nacelle yawing. The yaw bearing system is a plain bearing system with built-in friction and self-locking mechanisms.

The power transformer, which converts generator voltages to distribution-level voltages of up to 34.5 kV, is housed in the nacelle.

The glass fibre reinforced nacelle cover provides protection for the components in it. A central opening provides access to the nacelle from the tower. The nacelle houses the internal 800-kg (1760-lb.) service crane. As an option, this can be enlarged for the hoisting of main components (SWL = 6400 kg, (14080 lbs.)).

The steel tower is supplied with the standard Vestas American Wind Technology coating system as specified in Section 7. The customer may choose to use an optional system based upon specific environmental conditions of the proposed site.

4. General overview

Model	Rotor Diameter	Nominal RPM	Hub Height
V80 - 1.8	80 m [264 ft.]	15.5/16.8	60/67/78 m. [198/221/257 ft.]

5. OptiSlip® description

Asynchronous (induction) generator slip is defined as the difference between the synchronous speed and the actual generator speed. The standard slip for big, non-regulated asynchronous generators is about 1%, such that the rpm value is 1% higher when the generator is completely loaded, than without the load. Thus, speed and load changes are interdependent.

The Vestas OptiSlip® allows the generator slip to vary from 1% to 10%, reducing speed and load interdependency. Through OptiSlip® technology, the excess power of a sudden wind gust is not sent directly to the electrical. As a further advantage, the resulting mechanical loads on the wind turbine are also reduced.

Nevertheless, wind power during a wind gust is not lost, but briefly stored in a flywheel consisting of blades, gear and generator. The power during a wind gust leads to a short acceleration condition. The Vestas OptiSlip® with the Vestas pitch regulation system then reduces the rpm to a constant speed. At that time the stored power is released and sent to the electrical grid.

Vestas OptiSlip® provides the benefit of smooth electrical grid power quality, while minimising wind turbine loads.

Vestas OptiSlip® was introduced in 1994 and is operating successfully on thousands of Vestas wind turbines around the world.

6. Power Curves and Sound Levels

6.1 Power Curve for Vestas V80 - 1.8 MW, IEC class I

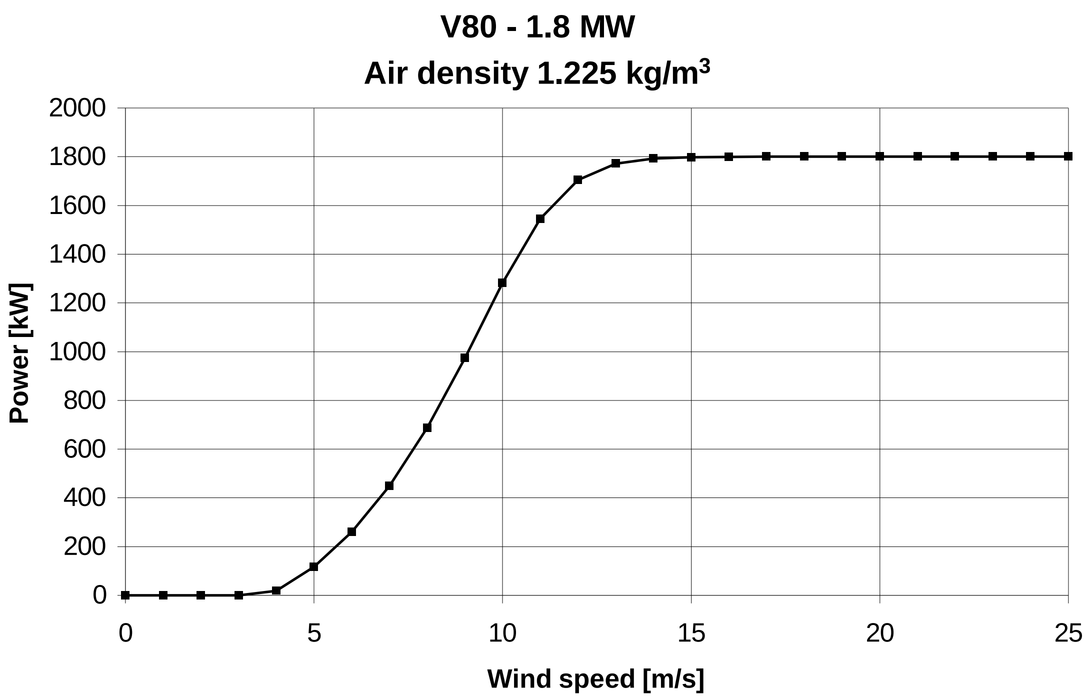
The Power Curve is calculated using NACA 63 profile series and FFA-W3.
The parameters for calculated curves are:

Frequency:	60 Hz.
Rotor diameter:	80 meters [264 ft.]
Nominal Rotor speed:	16.8 rpm.
Tip angle:	Pitch regulated
Turbulence:	10 %

The power curve is measured on the low-voltage side of the transformer.
Transformer and high-voltage cable losses are not accounted for.

Electrical-power [kW] as a function of wind speed [m/s] at hub height and density [kg/m³]									
V_{10} [m/s]	**1.225**	**1.06**	**1.09**	**1.12**	**1.15**	**1.18**	**1.21**	**1.24**	**1.27**
4	18,1	11,3	12,5	13,8	15,0	16,2	17,5	18,7	19,9
5	116	96,3	100	104	107	111	115	118	122
6	260	221	228	235	242	249	256	263	270
7	449	385	396	408	420	432	443	455	467
8	688	591	609	627	644	662	679	697	715
9	974	838	863	888	912	937	962	986	1011
10	1282	1110	1142	1174	1205	1236	1267	1296	1325
11	1546	1376	1412	1445	1476	1506	1533	1558	1581
12	1705	1590	1618	1642	1663	1681	1697	1711	1723
13	1771	1717	1732	1744	1754	1762	1768	1774	1778
14	1792	1773	1778	1783	1787	1789	1792	1793	1795
15	1798	1792	1794	1795	1796	1797	1798	1798	1799
16	1800	1798	1798	1799	1799	1799	1799	1800	1800
17	1800	1799	1800	1800	1800	1800	1800	1800	1800
18-25	1800	1800	1800	1800	1800	1800	1800	1800	1800

Wind speed is represented as a 10-minute average value with a reference point at the hub height and perpendicular to the rotor plane.



6.2 Annual Production V80 - 1.8 MW <u>IEC class I</u>

The estimated production is corrected to the standard air density of 1.225 kg/m3 and calculated on the assumption that the availability is 100 %, 78 m [257.4 ft.] hub height with a 25 m/s stop-wind speed.

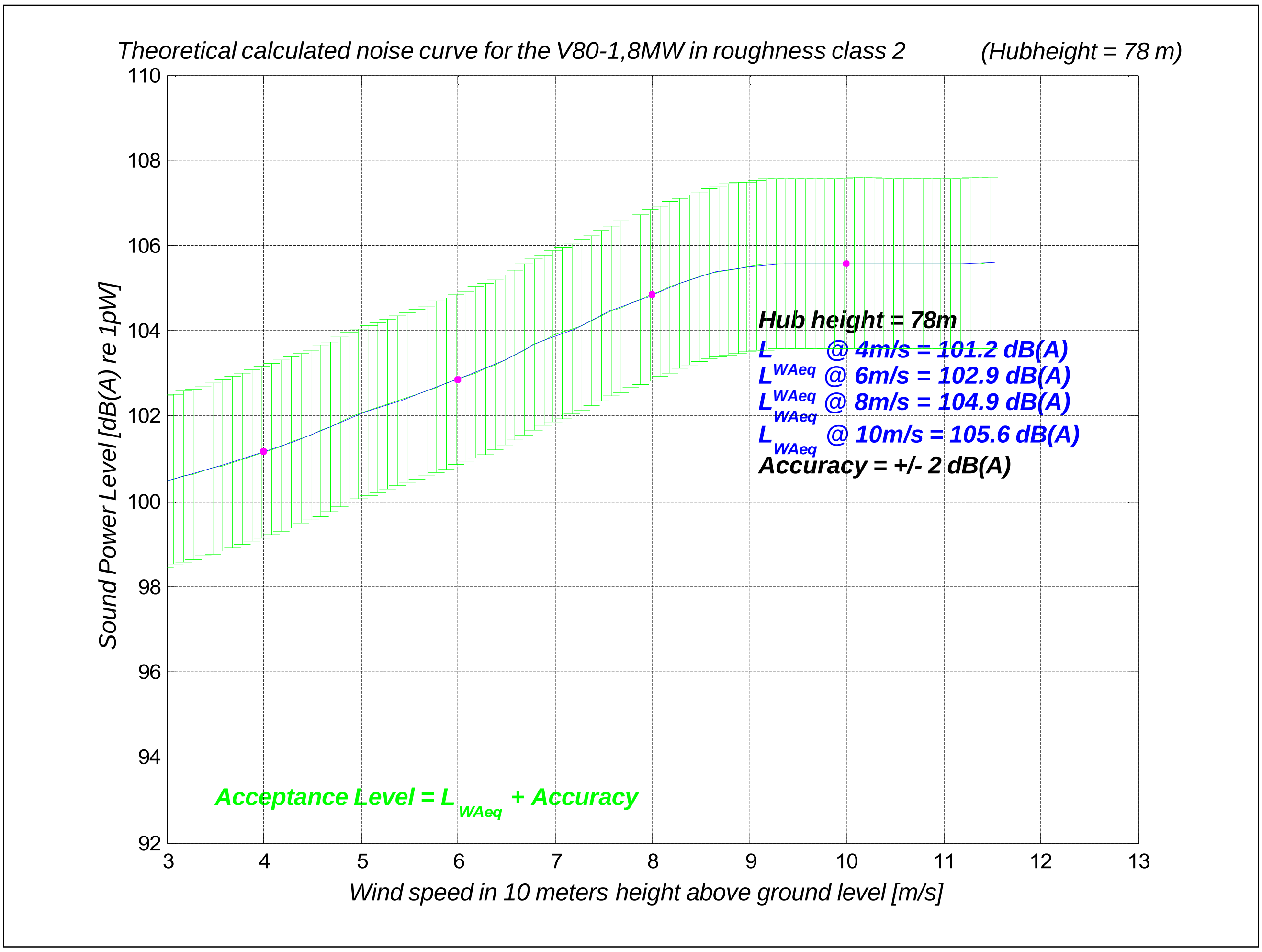
Annual Production [MWh]			
Mean Wind speed [m/s]	**C = 1.5**	**C = 2.0**	**C = 2.5**
5	2858	2363	1995
6	4110	3806	3495
7	5267	5269	5143
8	6259	6622	6735
9	7058	7797	8158
10	7664	8762	9363

Vestas Wind Systems A/S calculates the annual Energy output utilising a Weibull Distribution for the four (4) Danish wind roughness classes. The annual energy output is calculated on the assumption that the availability is 100 %, 78.0 m [257 ft.] hub height and 25 m/s stop- wind speed.

Roughness Class	MWh/year
0	7706
1	6166
2	5262
3	3937

6.3 Noise Curves V80 – 1.8MW IEC class I

All noise curves are calculated at 8 m/s at a 10-m [33 ft.] height.



6.4 Power Curve for Vestas V80 - 1.8 MW, IEC class II

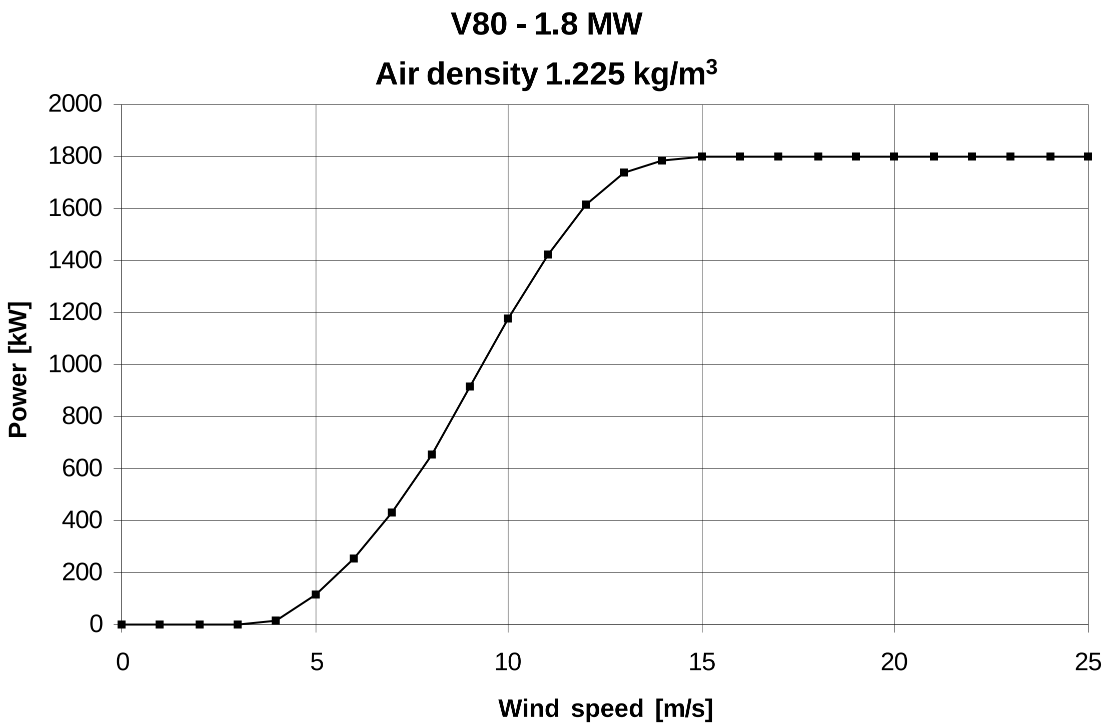
The Power Curve is calculated using NACA 63 profile series and FFA-W3.
The parameters for calculated curves are:

Frequency:	60 Hz.
Rotor diameter:	80 meters [264 ft.]
Nominal Rotor speed:	15.5 rpm.
Tip angle:	Pitch regulated
Turbulence:	10 %

The power curve is measured on the low-voltage side of the transformer.
Transformer and high-voltage cable losses are not accounted for.

Electrical-power [kW] as a function of wind speed [m/s] at hub height and density [kg/m^3]									
V_{10} [m/s]	**1.225**	**1.06**	**1.09**	**1.12**	**1.15**	**1.18**	**1.21**	**1.24**	**1.27**
4	12.9	5.3	6.7	8.1	9.4	10.8	12.2	13.6	14.9
5	116	94,4	98,3	102	106	110	114	118	122
6	252	212	219	226	234	241	249	256	263
7	432	367	378	390	402	414	426	438	450
8	657	560	578	595	613	630	648	666	683
9	914	782	806	830	854	878	902	926	950
10	1179	1011	1042	1072	1103	1133	1163	1194	1224
11	1424	1233	1269	1305	1341	1375	1408	1440	1472
12	1619	1437	1475	1512	1549	1580	1606	1631	1656
13	1735	1610	1638	1667	1695	1716	1729	1741	1754
14	1784	1725	1740	1754	1769	1778	1782	1786	1789
15	1797	1779	1784	1789	1793	1796	1797	1798	1798
16	1800	1796	1797	1798	1799	1800	1800	1800	1800
17	1800	1799	1800	1800	1800	1800	1800	1800	1800
18-25	1800	1800	1800	1800	1800	1800	1800	1800	1800

Wind speed is represented as a 10-minute average value with a reference point at the hub height and perpendicular to the rotor plane.



6.5 Annual Production V80 - 1.8 MW IEC class II

The estimated production is corrected to the standard air density of 1.225 kg/m3 and calculated on the assumption that the availability is 100 %, 78 m [257.4 ft.] hub height with a 25 m/s stop-wind speed.

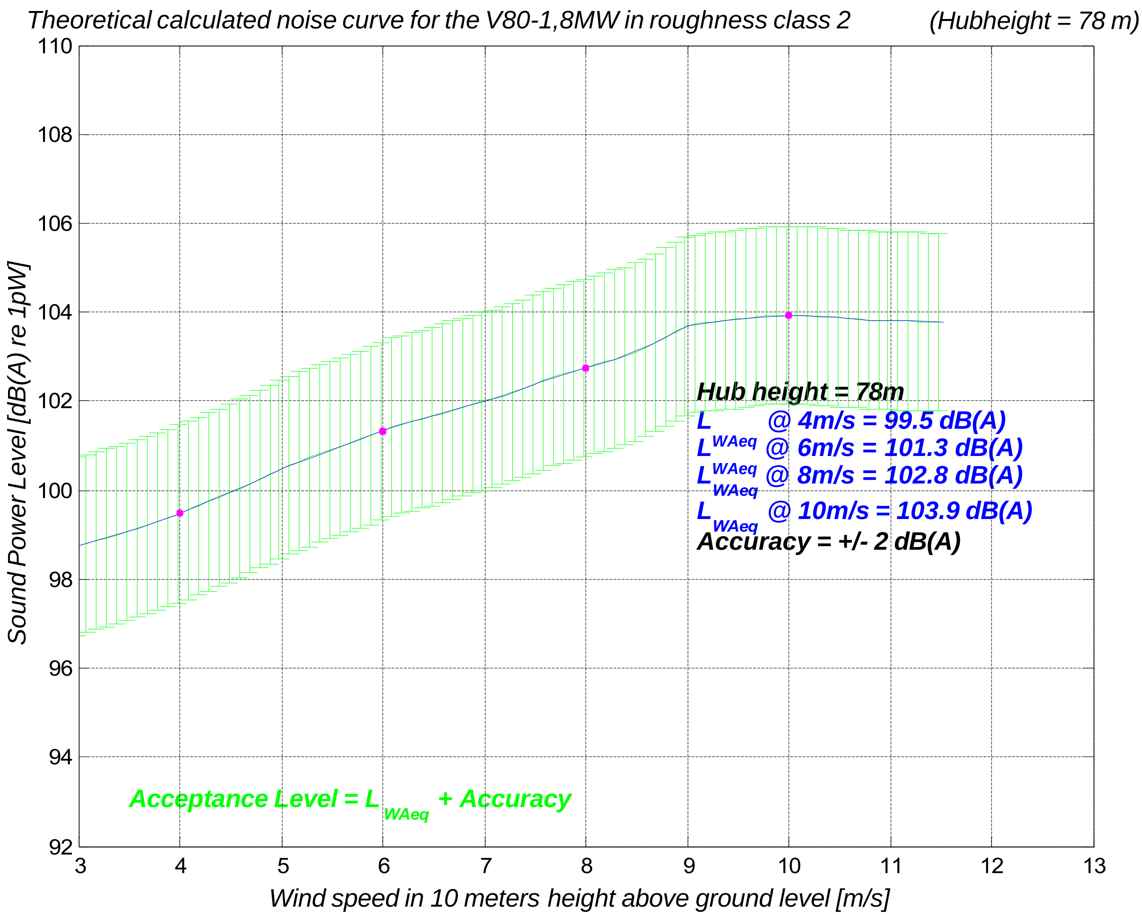
Annual Production [MWh]			
Mean Wind speed [m/s]	**C = 1.5**	**C = 2.0**	**C = 2.5**
5	2.723	2.243	1.900
6	3.932	3.613	3.309
7	5.063	5.023	4.872
8	6.041	6.346	6.410
9	6.836	7.512	7.813
10	7.444	8.480	9.022

Vestas Wind Systems A/S calculates the annual Energy output utilising a Weibull Distribution for the four (4) Danish wind roughness classes. The annual energy output is calculated on the assumption that the availability is 100 %, 78.0 m [257 ft.] hub height and 25 m/s stop- wind speed.

Roughness Class	MWh/year
0	7.410
1	5.886
2	5.006
3	3.734

6.6 Noise Curves V80 – 1.8MW IEC class II

All noise curves are calculated at 8 m/s at a 10-m [33 ft.] height.



7. Specifications

7.1 Rotor

Diameter:	80 m [264 ft.]
Swept area:	5027 m^2 [54,114 ft^2]
Rotational speed static, rotor:	16.8 RPM (IEC Class I) 15.5 RPM (IEC Class II)
Rotational direction:	Clockwise (front view)
Orientation:	Upwind
Tilt:	6°
Blade coning	2°
Number of blades:	3
Aerodynamic brakes:	Full feathering

7.2 Blades

Principle:	Shells bonded to supporting beam
Material:	Glass fibre reinforced epoxy
Blade connection:	Steel root inserts
Air foils:	NACA63 profile series and FFA-W3
Length:	39 m [129 ft.]
Chord (width) (blade root/blade tip):	3.52 m /0.48 m [11.62 ft/1.6 ft]
Twist (blade root/blade tip):	13°/0°
Weight per blade:	Approx. 6,500 kg. (14,300 lbs.)

7.3 Blade bearing

Type:	4-point ball bearing

7.4 Blade hub

Type:	Cast ball hub
Material:	EN-GJS-400-18U-LT

7.5 Main shaft

Type:	Forged, hollow shaft
Material:	42CrMo4 V / EN10083

7.6 Bearing housing

Type:	Cast foot housing with lowered centre
Material:	EN-GJS-400-18U-LT

7.7 Main bearings

Type:	Spherical roller bearings from recognised suppliers

7.8 Machine foundation

Type:	Cast EN-GJS-400-18U-LT

7.9 Yaw system

Type:	Plain bearing system with built-in friction
Material:	Forged yaw ring: heat-treated. Plain bearings: PETP.
Yawing speed:	< 0.5°/sec

7.10 Yaw gears

Type:	Planetary-/worm gear combination, 2 step planetary/1 step self locking worm gear
Motor:	2.5 kW, 6 pole, asynchronous (induction)

7.11 Steel Tower

Type:	Conical tubular
Material:	ASTM A709-Grade 36 or 50
Surface treatment:	Painted in accordance with ISO 12944-2
Corrosion class, outside:	C3
Corrosion class, inside	C3
Top diameter for all towers:	2.3 m (7.6 ft)
Bottom diameter for all towers	4.0 m (13.2 ft)
	Exact Hub Height
3-section, modular tower (60 m):	60 m (198 ft)
3-section, modular tower (67 m):	67 m (221 ft)
4-section, modular tower (78 m):	78 m (257 ft)

The exact hub height includes 0.4 m [1.3 ft] distance from the top of the foundation to the top of the foundation insert section flange , and 1.7 m [5.61 ft]distance from the top flange to the centre of the hub.

7.12 Gearbox

Type:	1 planetary stage/2 helical stages
Ratio:	60 Hz: 1:120.6
Cooling:	Oil-pump with oil-cooler
Oil heater:	2 kW
Oil filtration:	3 μm off-line filter unit + 10μm inline filter
Manufacturer:	Vestas has a number of sub-suppliers of gearboxes. All gearboxes are in compliance with Vestas specifications.

7.13 Couplings

Main shaft-gearbox:

Type:	Shrink disc, conical

Gearbox:

Type:	Composite shaft

7.14 Generator

Type:	Asynchronous [induction] with wound rotor, slip-rings and VRCC (OptiSlip® technology)
Rated power:	1.8 MW
Voltage:	690 VAC
Frequency:	60Hz
No. of poles:	4
Class of insulation:	F or better
Class of protection:	IP54
Slip regulation interval:	1- 10 %
Nominal slip:	4%
Nominal speed:	1872 RPM
Power factor, generator:	≥0.88
Rated current:	≤1712 Amps
Power factor correction:	900 kVar
Resulting power factor:	0.999
Resulting current:	1507 Amps

7.15 Parking brake

Type:	Disc Brake
Diameter:	600 mm [24 inches]
Disc material:	SJV300

7.16 Hydraulic unit

Pump capacity:	44 l/min (11.6 gal/min)
Max. Pressure:	200 bar (2900 psi)
Brake pressure:	28 bar (406 psi)
Oil quantity:	300 l (79.3 gal)
Motor:	18.5 kW

7.17 Anemometer and Wind Direction Sensor

Type:	1 ultrasonic sensor

7.18 Lightning Protection

Down-conductors in blades	A down-conductor is placed in each rotor blade
Equipotential bonding	The machine frames, crane bars, crane pillars and the tower are equipotentially bonded

7.19 Control unit

Power current:	
Voltage:	3 x 690 VAC
Frequency	60 Hz
Power supply for light:	110 VAC
Computer:	
Communication:	ArcNet
Program memory:	EPROM (flash)
Programming language:	Modula-2
Configuration:	Modules
Operation:	Numeric keyboard + function keys
Display:	4 x 40 characters
Processor Supervision/control:	Yawing
	Hydraulics
	Ambient Surroundings (wind, temperature)
	Rotation
	Generator
	Pitch system
	Grid
	Power factor correction
	Thyristors
	Remote monitoring
Information:	Operating data
	Production
	Operation log
	Alarm log
Commands:	Run/Pause
	Man. Yaw start/stop
	Maintenance routine
REMOTE SUPERVISION	Possible serial communication connection.

7.20 Transformer

Type:	Cast resin
Rated Power:	1850 kVA
High voltage:	6 – 34,5 kV (36kV equipment voltage)
Frequency	60 Hz
Vector group:	Yn/Yn
Low voltage:	690 Vac
HV – Tas:	+/- 2 x 2.5%
Impedance voltage:	6.8%

7.21 Weights

[Weights in Tons = 1000 kg]

Nacelle: [63 Tons]
Rotor: [35 Tons]

8. Installation

8.1 Terrain

Particular considerations must be taken if the terrain has a slope of more than 10° within a 100-m [330ft.] radius of the turbine. In all cases, it is recommended to consult Vestas prior to final site selection.

8.2 Climatic conditions

The turbine is designed for an ambient temperature range of -20°C [-4ºF] to +40°C [+104ºF]. At temperatures less than –20°C [-4ºF] and greater than +40°C [+104ºF] the turbine will not generate power, and special considerations must be undertaken.

The turbine has been designed in accordance with IEC 61400-1 class I_A wind conditions and can be placed in wind farms with a minimum distance of 5 (five) rotor diameters (400 m/1320 ft) between all turbines. If the turbines are placed in a single row, perpendicular to the predominant wind direction, the distance between adjacent turbines must be a minimum of 4 (four) rotor diameters (320 m/1056 ft).

The relatively humidity can be 100 % (max. 10 % of the time).

Corrosion
Corrosion protection is in accordance with ISO Standard12944-2.

All Vestas turbines are produced and protected according to the following corrosion classes:

Outside fittings and sensors are corrosion protected to class **C3**.

Inside surfaces, directly exposed to outside air, e.g. inside nose cone and transformer housing are corrosion protected to class **C3**.

Inside surfaces, not directly exposed to outside air, e.g. component inside the nacelle, are corrosion protected to class **C3**.

Towers are deliverable in different corrosion protection classes. Standard towers are protected to class **C3** on outside surfaces and **C3** inside. Foundations are classified according to ISO Standard 12944-2, corrosion class **IM3.**

8.3 Grid connection

The turbine can be connected to a medium-voltage grid at a range of 6-34.5 kV, where 36 kV (U_m) is the highest equipment voltage. The electrical grid medium-voltage cable connection is made at the tower base.

The low-voltage/medium-voltage transformer must be special-ordered to correspond to the desired grid voltage. At the turbine ordering stage, Vestas will need precise information about the interconnecting grid voltage so that the low voltage/medium voltage transformer's nominal voltage and winding connection can be correctly specified. Winding connections in both Y-Δ and Y-Y (low voltage/medium voltage) configurations are available. As an option, Vestas can also provide a medium voltage switch gear installation to isolate the turbine from the interconnecting grid.

The medium-voltage grid voltage levels shall be within +5/-5% of nominal levels, with frequency variations of +2/-3Hz permitted.

NOTE: GRID FREQUENCY FLUCTUATIONS OF AN INTERMITTENT OR RAPID NATURE CAN CAUSE SERIOUS TURBINE DAMAGE AND SHOULD BE MINIMIZED.

As an average, grid drop-out (loss of grid power) shall not take place more than once a week over the turbines' lifetime.

The grounding system must be designed (by others) in accordance with the local soil conditions. The resistance to neutral earth must be according to the requirements of the local authorities. Vestas requires that the electrical ground connection has a maximum resistance of 10 Ω.

Harmonics and Capacitors for Power Factor Correction
The 5th and 7th harmonics are sinusoidal voltages with frequencies of 300 Hz and 420 Hz, respectively. Harmonics are caused by different equipment (e.g. welding machines, converters and drives) connected to the same power supply systems as the wind turbine. Harmonics in power supply system may cause overload conditions that could lead to a reduction in the lifetime of the power factor correction capacitors.

The turbine is equipped with reactors to reduce the harmonic load at the capacitors. The power factor correction system is designed to operate at a harmonic spectrum according to the following European standards: VDE 0160, IEC 1000-2-2 and EN 50160.

9. General reservations, Notes and Disclaimers

- All data are valid at sea level (ρ=1.225 kg/m^3). Machine de-rating may be necessary at other altitudes.
- 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 electrical 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.
- If the wind turbine is sited at elevations greater than 1000 m (3300 ft) above sea level, a higher than usual temperature rise may occur in electrical components. In such cases, a periodic power reduction from rated electrical output may occur. This may occur even when the ambient temperature remains within specified limits.
- Furthermore, sites situated at greater than 1000 m (3300 ft.) above sea level usually experience an increased risk of icing in most climates.
- Because of continuous development and product upgrade, Vestas reserves the right to change or alter these specifications at any time.

10. Performance Note

THE PERFORMANCE OF THE VESTAS V80-1.8 MW WIND TURBINES CAN AND WILL VARY DEPENDING ON NUMEROUS VARIABLES, MANY OF WHICH ARE CONSIDERED AS PART OF THE PERFORMANCE MEASUREMENT STANDARD SET FORTH IN THE GENERAL SPECIFICATIONS. MANY OF THESE VARIABLES INCLUDING, BUT LIMITED TO, SITE LOCATION, INSTALLATION, TURBINE CONDITION, TURBINE MAINTENANCE AND ENVIRONMENTAL/CLIMATIC CONDITIONS ARE BEYOND THE CONTROL OF VESTAS. UNLESS OTHERVISE CONTRACTUALLY AGREED IN WRITING, ALL PERFORMANCE SPECIFICATIONS SET FORTH IN THIS GENERAL SPECIFICATION INCLUDING, BUT NOT LIMITED TO, POWER CURVES, ANNUAL PRODUCTIONS AND NOISE EMISSIONS SHOULD BE USED FOR GUIDEANCE ONLY, AND NOT AS A PREDICTOR OR GUARANTEE OF FUTURE PERFORMANCE. FOR ADDITIONAL INFORMATION REGARDING THE INSTALLATION, MAINTENANCE AND PERFORMANCE OF THE VESTAS V80–1.8MW WIND TURBINES, PLEASE CONTACT VESTAS DIRECTLY.