Appendix 4:

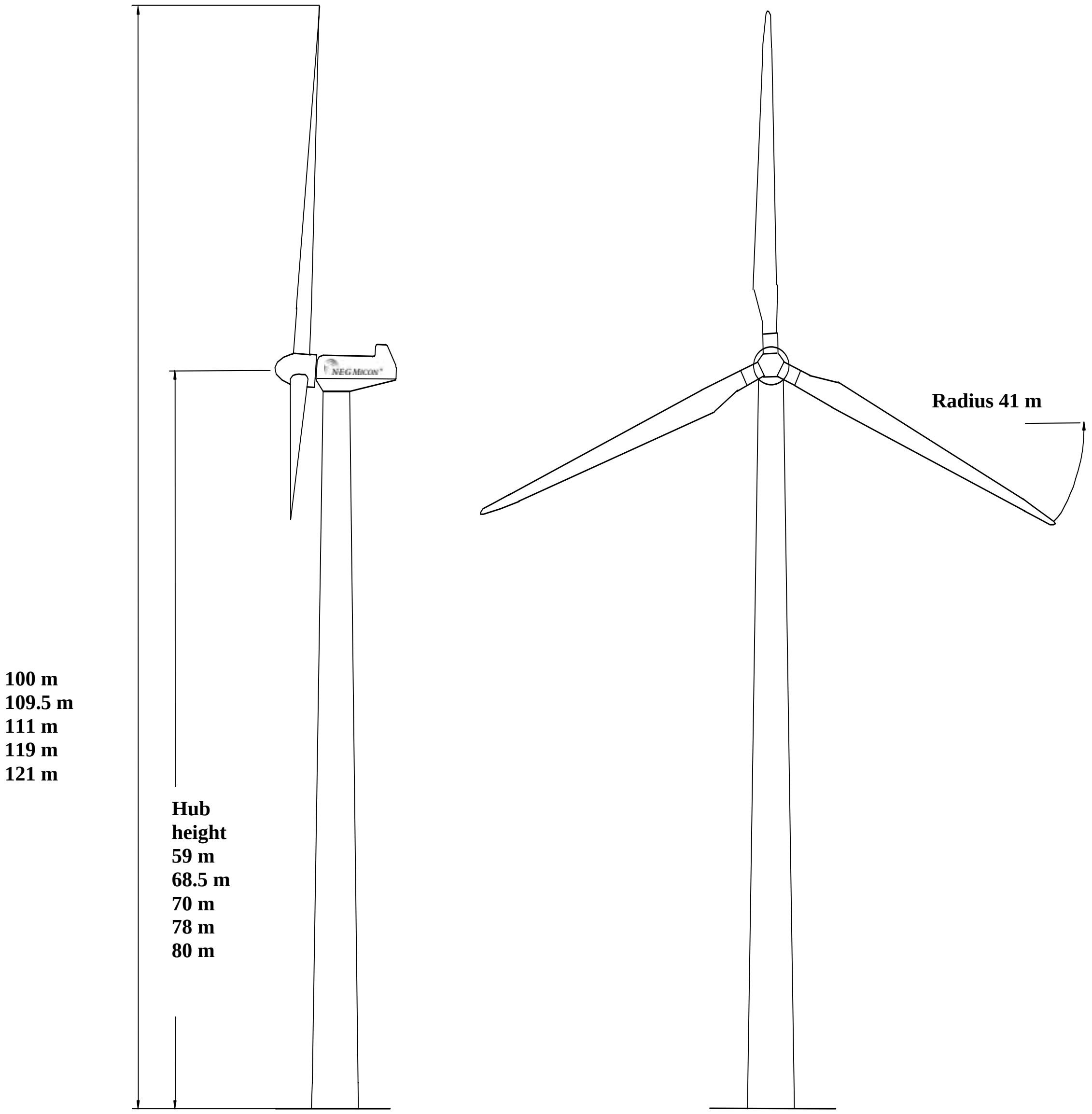
Vestas V82 and V90 Wind Turbine Specifications, and the Vestas V100 Wind Turbine Product Brochure

Class I
TSD 4000258-01 EN
2004-10-07

General Specification

V82-1.65 MW MK II
NM82/1650 Vers. 2

0	Illustration



1	Main Data			
		50 Hz	**60 Hz**	**60 Hz UL**
	Nominal Power	1650 kW	1650 kW	1650 kW
	Rotor diameter	82 m	82 m	82 m
	Swept area	5281 m^2	5281 m^2	5281 m^2
	Hub height. IEC IIb	59 m, 68.5 m, 70 m, 78 m	70 m, 78 m.	59 m, 70 m, 80 m
	Rotational speed	14.4 rpm	14.4 rpm	14.4 rpm

2	Nacelle Base Frame		
		50Hz	**60Hz**
	Material	EN-GJS-400-18U-LT	EN-GJS-400-18U-LT
	Standard colour	RAL 7035	RAL 7035
	Corrosion class, outside	Acc. to DS EN ISO 12944:C5 I	Acc. to DS EN ISO 12944:C5 I

3	Rotor		
		50Hz	**60Hz**
	Number of blades	3 pieces	3 pieces
	Tip speed (synchronous)	61.8 m/s	61.8 m/s
	Rotor shaft tilt	5°	5°
	Eccentricity (tower center to hub center)	3447 mm	3447 mm
	Solidity (Total blade area/rotor area)	5.0 %	5.0 %
	Power regulation	Active Stall®	Active Stall®
	Rotor orientation	Upwind	Upwind

4	Blades		
		50Hz	**60Hz**
	Type description	AL 40	AL 40
	Blade length	40 m	40 m
	Material	Carbon/wood/glass/epoxy	Carbon/wood/glass/epoxy
	Standard colour	RAL 7035	RAL 7035
	Gloss	Class 2: (30-70%) in accordance with (1), to be measured acc. to DS/ISO2813	Class 2: (30-70%) in accordance with (1), to be measured acc. to DS/ISO2813
	Type of rotor air brake	Full blade	Full blade
	Blade profiles	• FFA -W3, NACA 63.4	• FFA - W3, NACA 63.4
	Twist	20°	20°
	Largest chord	3.08 m	3.08 m
	Blade area (projected)	86 m^2	86 m^2
	Note! (1) Technical Criteria for Danish Approval Scheme for Wind Turbines		

5	Blade bearing		
		50 Hz	**60 Hz**
	Type description	Ball bearing	Ball bearing
	Number of bearings	3 pcs.	3 pcs.

6	Hub		
		50Hz	**60Hz**
	Type description	Spherical	Spherical
	Material	EN-GJS-400-18U-LT	EN-GJS-400-18U-LT
	Corrosion class, outside	Acc. to DS EN ISO 12944:C5 I	Acc. to DS EN ISO 12944:C5 I

7	Main shaft		
		50Hz	**60Hz**
	Type description	Forged shaft and flange	Forged shaft and flange
	Material	34CrNiMo6 + QT	34CrNiMo6 + QT
	Corrosion class	Acc. to DS EN ISO 12944:C2	Acc. to DS EN ISO 12944:C2

8	Main Bearing		
		50Hz	**60Hz**
	Type description	Spherical roller bearing	Spherical roller bearing
	Number of	1 piece	1 piece
	Lubrication	Oil pump	Oil pump

9	Main Bearing Housing		
		50Hz	**60Hz**
	Type description	Flange bearing	Flange bearing
	Material	EN-GJS-400-18U-LT	EN-GJS-400-18U-LT

10	Gearbox		
		50 Hz	**60Hz**
	Type description	1. step planet, 2. step helical	1. step planet, 2. step helical
	Gear house material	Cast	Cast
	Ratio	1:70.2	1:84.3
	Mechanical power	1800 kW	1800 kW
	Bending strength acc. to ISO 6336	S_F > 1.6	S_F > 1.6
	Surface durability acc. to ISO 6336	S_H > 1.25	S_H > 1.25
	Scuffing safety acc. to DNV 41.2	S_S > 1.3	S_S > 1.3
	Shaft seals	Labyrinth	Labyrinth
	Oil sump	App. 250 l	App. 250 l

11	Cartridge Gear Heater - for Arctic Version only		
		50 Hz	**60 Hz**
	Rating	800 W/ pcs.	800 W/ pcs.
	Number of	4 pieces	4 pieces

12	Oil pump		
		50 Hz	**60Hz**
	Voltage	3 x 690 V	3 x 480 V

13	Heat Exchange Unit (Water/Oil)		
		50 Hz	**60 Hz**
	Cooling capacity	41.3 kW	41.3 kW

14	Oil Cooler		
		50 Hz	**60 Hz**
	Cooling capacity	37.5 kW	37.5 kW

15	Water Pump		
		50 Hz	**60Hz**
	Voltage	1 x 230 V	3 x 480 V

16	Water Cooler/ Radiator		
		50 Hz	**60 Hz**
	Cooling capacity	46.2 kW	46.2 kW

17	Electrical Nacelle Heater - for Arctic Version only		
		50 Hz	**60Hz**
	Voltage	3 x 690 V	3 x 600 V
	Power	20 kW	20 kW
	Number of heaters	2 pieces	2 pieces

18	Mechanical Shaft Brake		
		50 Hz	**60Hz**
	Type description	Active Brake	Active Brake
	Brake disc	Steel, mounted on high speed shaft	Steel, mounted on high speed shaft
	Number of calipers	2 piece	2 piece

19	Hydraulic Power Unit for Mechanical Shaft Brake		
		50 Hz	**60Hz**
	Voltage	3 x 690 V	3 x 480 V
	Working pressure range	140-150 bar	140-150 bar
	Oil capacity	11 l	11 l

20	Coupling		
		50 Hz	**60Hz**
	Type description	Flexible coupling, constant rpm	Flexible coupling, constant rpm

21	Generator			
			50 Hz	60 Hz
	Type description		1 speed generator, water cooled	1 speed generator, water cooled
	Rated power	P_N	1650 kW	1650 kW
	Apparent power	S_N	1805 kVA	1808 kVA
	Rated current	I_N	1510 A	1740 A
	Max power at Class F	P_{Fmax}	1815 kW	1815 kW
	Max current at Class F	I_{Fmax}	1661 A	1914 A
	No load current	I_0	400 A	430 A
	Reactive power consumption at rated power (tolerance. acc to IEC 60034-1)	Q_N	731 kvar	740 kvar
	Reactive power consumption at no load (tolerance. acc to IEC 60034-1)	Q_0	478 kvar	447 kvar
	Number of poles	P	6	6
	Synchronous rotation speed	n_0	1000 rpm	1200 rpm
	Rotation speed at rated power	n_N	1012 rpm	1214 rpm
	Slip at rated power	s_N	1.20 %	1.17 %
	Voltage	U_N	3 x 690 V	3 x 600 V
	Frequency	F	50 Hz	60 Hz
	Coupling		Δ	Δ
	Enclosure		IP54	IP54
	Insulation class/ Temperature increase		F/B	F/B

22	Yaw System – Ball Bearing Slewing Ring		
		50 Hz	60 Hz
	Type description	Ball bearing, internal gearing	Ball bearing, internal gearing

23	Yaw System – Yaw Gear and Motors		
		50 Hz	60 Hz
	Type description	Planetary gear motor	Planetary gear motor
	Gear ratio of yaw gear unit	app. 1:1687	app. 1:1687
	Voltage	3 x 690 V	3 x 480 V
	Rotational speed at full load	920 rpm	1140 rpm
	Number of yaw gears	6 pieces	6 pieces

24	Yaw System – Yaw Brake		
		50 Hz	60 Hz
	Type Description	Hydraulic disc brake	Hydraulic disc brake
	Number of Yaw Friction Units	6 pieces	6 pieces

25	Hydraulic Power Unit for Yaw Brake		
		50 Hz	60 Hz
	Voltage	3 x 400/ 3x 690 V	3 x 480 V
	Working pressure range	140-150 bar	140-150 bar
	Oil capacity	App. 10 l.	App. 10 l.

26	Tower		
		50 Hz	60 Hz
	Type Description	Conical, tubular	Conical, tubular
	Material	Welded steel plate	Welded steel plate
	Corrosion class, outside	Acc. to DS EN ISO 12944: C5 I	Acc. to DS EN ISO 12944: C5 I
	Colour	RAL 7035	RAL 7035
	Access conditions	Internal, safety harness, ladder cage	Internal, safety harness, ladder cage

27	Wind Turbine Main Panel/ Control panel/ phase comp. panel		
		50 Hz	**60 Hz**
	Voltage	3 x 690 V	3 x 600 V
	Frequency	50 Hz	60 Hz
	Cut-in system	Soft with thyristors	Soft with thyristors
	Design Standard	IEC	UL

28	Electrical Grid Requirements		
		50 Hz	**60Hz**
	Max. voltage	+10 % (60 sec.)	+10 % (60 sec.)
	Min. voltage	-10 % (60 sec.)	-10 % (60 sec.)
	Max. voltage	+12.5 % (0.1 sec.)	+12.5 % (0.1 sec.)
	Min. voltage	-15 % (0.1 sec.)	-15 % (0.1 sec.)
	High frequency	+1 Hz (0.2 sec.)	+1 Hz (0.2 sec.)
	Low frequency	- 2 Hz (0.2 sec.)	- 2 Hz (0.2 sec.)
	Maximum asymmetri current	15 % (60 sec.) – phase to ground	15 % (60 sec.) – phase to ground
	Maximum asymmetri voltage	2 % (60 sec.) – phase to ground	2 % (60 sec.) – phase to ground
	Maximum short circuit current	25 kA at 690V	30 kA at 600V
	Single harmonic	Max 1% of any single harmonic	Max 1% of any single harmonic
	Total harmonic distortion	Max 3% total harmonic distortion	Max 3% total harmonic distortion
	Connection	• Solidly grounded wye at secondary (690 V) side of transformer	• Solidly grounded wye at secondary (600 V) side of transformer

29	Integrated Grid Connection System, IGC System, Transformer in tower - Optional (IGC is not delivered in the US)		
	Power Transformer incl. Metal Enclosure		
		50 Hz	60 Hz
	Type description	Cast Resin (dry type)	Cast Resin (dry type)
	Apparent power	1800 kVA	1800 kVA
	Primary voltage	10 – 24 kV+/- 2 x 2.5 %	10 – 24 kV+/- 2 x 2.5 %
	Secondary voltage	0.690 kV	0.600 kV
	Frequency	50 Hz	60 Hz
	Coupling group	Dyn, Solidly grounded wye at 690 V	Dyn, Solidly grounded wye at 600 V
	Switch gear		
	Type description	Gas insulated SF6 ring main unit	Gas insulated SF6 ring main unit
	Nominal voltage	24 kV	24 kV
	Frequency	50 Hz	60 Hz

31	Climate and Site Conditions regarding structural design		
		50 Hz – IEC IIb	**60 Hz – IEC IIb**
	Design life time	20 years	20 years
	Temperature interval for operation	See specifications below	See specifications below
	Temperature interval for structure	See specifications below	See specifications below
	A-factor	9.59 m/s	9.59 m/s
	Form factor, c	2.0	2.0
	Annual average wind speed	8.5 m/s	8.5 m/s
	Wind shear	0.20	0.20
	Extreme wind speed	42.5 m/s (10 min. average)	42.5 m/s (10 min. average)
	Survival wind speed	59.5 m/s (3 sec. average)	59.5 m/s (3 sec. average)
	Automatic stop limit	20 m/s (10 min. average)	20 m/s (10 min. average)
	Re-cut in	18 m/s (10 min. average)	18 m/s (10 min. average)
	Characteristic turbulence intensity acc. to IEC 61400-1 (15 m/s)	16% (including wind farm turbulence)	16% (including wind farm turbulence)
	Air density	1.225 kg/m3	1.225 kg/m3
	Maximum in-flow angle	8°	8°

32	Specific Climate and Site Conditions			
		Standard (only 50 Hz)	**Tropical -20 to +40°C (50 + 60 Hz)**	**Arctic (50 + 60 Hz)**
	Temperature interval for operation[1,2,3]	-20 to +30°C	-20 to +35°C (+40°C)	-30 to +30°C
	Temperature interval for structure	-20 to +50°C	-20 to +50°C	-40 to +50°C

[1] Note! For Tropical! Rated power is reduced to 1500 kW for temperature between +35°C and +40°C.
[2] Note! No operation if temperature is below -10°C in control panel or gear oil sump. Heating systems are optional.
[3] Note! If the windturbine is placed more than 1000m above sea level, a higher temperature rise than usual might occur in the generator, the transformer and other electrical components. In this case a periodic reduction of rated power might occur, even if the ambient temperature is within specified limits. Furthermore increased risk of icing up occur at sites more than 1000m above sea level.

33	**Conditions for Power Curve (at hub height)**		
		50 Hz	**60Hz**
	Air density	1.225 kg/m^3	1.225 kg/m^3
	Wind shear	0.12-0.16	0.12-0.16
	Turbulence intensity	11-16 %	11-16 %
	Blades	Clean	Clean
	Ice/snow on blades	No	No
	Leading Edge	No damage	No damage
	Rain	No	No
	Terrain	IEC 61400-12	IEC 61400-12
	Inflow angle	0±2 °	0±2 °
	Grid frequency	50 ±0.5	60±0.5 Hz
	Verification acc. to	IEC 61400-12	IEC 61400-12

Class 1
Item no. 950010.R1
2004-03-02

General Specification

V90 – 3.0 MW

60 Hz
Variable Speed Turbine

WWW.VESTAS.COM

Vestas Wind Systems A/S
Smed Soerensens Vej 5
DK-6950 Ringkoebing

Contents ....Page

1. General Description

The VESTAS V90 – 3.0 MW is a pitch regulated upwind wind turbine with active yaw and a three-blade rotor.

The VESTAS V90 – 3.0 MW has a rotor diameter of 90 m with a generator rated at 3.0 MW.
The turbine utilises the OptiTip® and the variable speed concepts. With these features rated power will be maintained even in high wind speeds, regardless of air temperature and air density, and the wind turbine is able to operate the rotor at variable speed (RPM). At low wind speeds the OptiTip® system and variable speed operation maximise the power output by giving the optimal RPM and pitch angle, which also minimises the sound emission from the turbine.

1.1 Nacelle Description

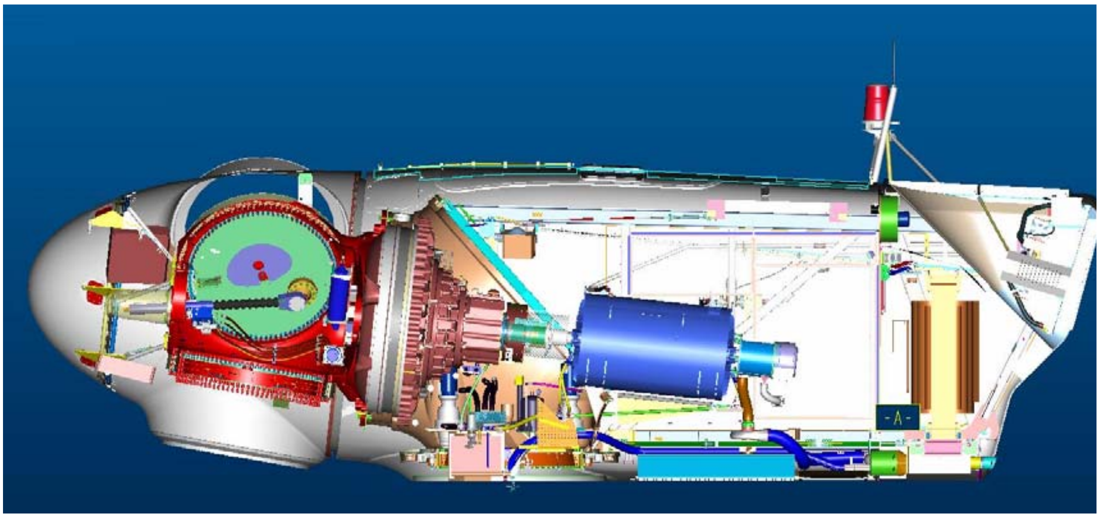


Fig. 1 V90 3.0 MW Nacelle

The nacelle cover is made of fibreglass. An opening in the floor provides access to the nacelle from the tower.
The roof section is equipped with skylights, which can be opened to access the roof and the wind sensors.
Wind sensors are mounted on the nacelle roof. Aviation lights, if any, are also placed on top of the nacelle.

1.1.1 Machine Foundation (the Bedplate)

The front of the nacelle bedplate is the foundation for the drive train, that transmits forces and torque from the rotor to the tower, through the yaw system. The front of the nacelle bedplate is made of cast steel. The nacelle cover is mounted on the nacelle bedplate.

The nacelle bedplate is in two parts and consists of a cast iron part and a girder structure.
The cast iron part serves as the foundation of the main gear and the generator. The bottom surface is machined and connected to the yaw bearing. The crane beams are attached to the top structure. The lower beams of the girder structure are connected at the rear end. The rear part of the bedplate serves as the foundation for controller panels, cooling system and transformer.
The four yaw-gears are bolted to nacelle bedplate.

The nacelle houses the internal 800 kg SWL service crane. The crane is a single system chain hoist. If any heavier parts need service, the service crane can be upgraded to 1600/10000 kg SWL.
The upgraded crane is able to lift and lower large elements such as parts of the gearbox and the generator.

1.1.2 Gearbox

The main gear transmits the torque from the rotor to the generator.
The gear unit is a combination of a 2-stage planetary gear and a 1-stage helical gear. The gear housing is bolted to the bedplate. The low speed input shaft is bolted directly to the hub without the use of a traditional main shaft.
The gearbox lubrication system is a forced feed system without the use of an integrated oil sump.

1.1.3 Yaw System

The yaw bearing system is a plain bearing system with built-in friction. The system enables the nacelle to rotate on top of the tower. The system transmits the forces from the turbine-rotor/nacelle to the tower.

Four electrical yaw gears with motor brakes rotate the nacelle.

1.1.4 The Brake System

The turbine brakes by full-feathering of the rotor blades. The individual pitch cylinders ensure triple braking safety.
Furthermore, a hydraulic system supplies pressure to a disc brake located on the main gear high-speed shaft. The disc brake system consists of 3 hydraulic brake callipers.

The disc brake is considered as the parking brake.

1.1.5 Generator

The generator is an asynchronous 4-pole generator with a wound rotor.

Variable speed allows varying the rotor speed within a wide speed range. This reduces power fluctuations in the power grid system as well as minimises the loads on vital parts of the turbine. Furthermore, the variable speed system optimises the power production, especially at low wind speeds. Variable speed technology enables control of the turbine reactive power factor between 0.96 inductive and 0.98 capacitive measured on the low voltage side.
The generator is water-cooled.

1.1.6 Transformer

The step up transformer is located in a separate compartment to the rear of the nacelle. The transformer is a three phase dry-type cast resin transformer specially designed for wind turbine applications.
The windings are delta connected on the medium voltage-side unless otherwise specified. The windings are connected in star on the low voltage-side (1000 V and 400 V). The 1000 V and 400 V systems in the nacelle are a TN-system, where the star point is connected to ground.
Surge arresters are mounted on the medium voltage (primary) side of the transformer.
The output voltages available are in 0.5 kV steps from 10 to 34.5 kV where 36kV(U_{m}) is the highest equipment peak voltage.

The transformer room is equipped with arc detection sensors.

1.1.7 The Cooling and Air-conditioning System

If the inside air temperature of the nacelle exceeds a certain level, flap valves will open to the outside. A fan engine will draw in outside air for cooling the nacelle air.

Gear lubrication oil, generator cooling water and the variable speed unit are cooled from a separate air intake, using separate water/air cooling systems. Water coolers are thermally insulated from other parts of the nacelle.
A separate fan cools the transformer.

The heat exchanger system is mounted in a separate compartment in the upper rear section of the nacelle.

1.2 Rotor V90

1.2.1 Hub / Nose Cone

The hub is mounted directly onto the gearbox, thereby eliminating the main shaft traditionally used to transmit the wind power to the generator through the gearbox.

1.2.2 Pitch Regulation

The V90 is equipped with a microprocessor controlled pitch control system called OptiTip®.Based on the prevailing wind conditions, the blades are continuously positioned to the optimum pitch angle.
The pitch mechanism is placed in the hub. Changes of the blade pitch angle are made by hydraulic cylinders, which are able to rotate the blade 95°. Every single blade has its own hydraulic pitch cylinder.

1.2.3 Hydraulics

A hydraulic system produces hydraulic pressure for the pitch systems in the hub. In case of grid failure or leakage, a backup accumulator system provides sufficient pressure to pitch the blades and stop the turbine.
A collector system prevents oil leaks, if any, from spreading outside the hub.

1.2.4 Blades

The blades are made of fibre glass reinforced epoxy and carbon fibres. Each blade consists of an inner beam encircled by two shells. The blades are designed for optimised output and minimised noise and light reflection. The V90 blade design minimizes the mechanical loads applied to the turbine.

The blade bearing is a double raced 4-point ball bearing bolted to the blade hub. Each blade has a lightning protection system consisting of lightning receptors on the blade tip and a copper wire conductor inside the blade.

1.3 Control and Regulation

1.3.1 Variable Speed Description

Variable speed ensures a steady and stable electric power production from the turbine.

The variable speed system consists of an asynchronous generator with wound rotor, slip rings and power converter. A power converter is connected to the rotor to control the generator at variable speed. In supersynchronous operation due to wind gusts, the excess rotor energy is dissipated in a chopper resistor.

The variable speed and the OptiTip system ensure energy optimisation, low noise operation and reduction of loads on all vital components.

The system controls the current in the rotor circuit of the generator. This gives precise control of the reactive power, and gives a smooth connection sequence when the generator is connected to the grid.

The reactive power control is as default set at 0 KVAr export/ import at 1000 V.

1.3.2 Vestas Multi Processor Controller

All functions of the wind turbine are monitored and controlled by microprocessor based control units called VMP (Vestas Multi Processor).
The VMP controller consists of several individual sub controller systems. Each system has separate operation tasks and communicate via an optical-based network (ArcNet).
The controller enclosures are located in the bottom of the tower, in the nacelle and in the hub.
The operating system is VxWorks®, which fulfils the demands for stability, flexibility and security that are expected in a modern, intelligent wind turbine.
Digital and analogue Input/Output functions in the turbine are interfaced via the use of distributed units communicating on the CAN-open protocol.

The VMP-controller is equipped with a battery backup system.

The VMP controller serves the following functions:

- Monitoring and supervision of the operation.
- Synchronising the generator to the grid during the connection sequence, in order to limit the in rush current.
- Operating of the turbine during various fault situations.
- Automatic yawing of the nacelle in accordance to the wind direction.
- OptiTip® -Controlling the blade pitch.
- Reactive power control and variable speed.
- Noise emission control.
- Monitoring of ambient conditions (wind, temperature, etc).
- Monitoring of the grid.

- Monitoring and logging of lightning strikes.
- Supervising of the smoke detection system.
- De-rating in case of critical high temperatures.

1.3.2.1 Active Damping of Tower Oscillations

In the nacelle two accelerometers are mounted for monitoring longitudinal and transverse oscillations. Such oscillations can in certain situations be introduced when the rotational frequency of the rotor is close to the natural inherent frequency (natural oscillation) of the tower, but also high wind speeds in combination with high turbulence may cause tower oscillations.
If the oscillations exceed a certain limit, the system will bring the turbine back to normal operating conditions.
To avoid stopping the turbine, tower oscillations are damped by changing the rotational frequency of the rotor and by pitching the blades.

To damp longitudinal oscillations the blades are pitched synchronously. Transverse oscillations are damped by individual pitch.

The turbine is only stopped if the active damping is not successful.

1.3.2.2 Active Damping of Drive Train Torsional Oscillations on Variable Speed Controlled Turbines

Oscillations that may occur on the drive train can be monitored by measuring the number of revolutions and can be damped via an active control of the generator.
If the oscillations exceed a certain limit, the system is activated in order to stop further escalation of the drive train oscillations.

1.4 Monitoring

1.4.1 Sensors

Data for controlling the turbine and the energy production is received from different sensors:

- Weather conditions: Wind direction, wind speed and temperature.
- Machine conditions: Temperatures, oil level and pressure, cooling water level, vibrations.
- Rotor activity: Speed and pitch position.
- Construction: Vibrations, lightning detectors.
- Grid connection: Active power, reactive power, voltage, current, frequency, Cosφ.

1.4.2 Sensor Features

1.4.2.1 Ultrasonic Wind Sensors

The nacelle is equipped with two redundant ultrasonic wind sensors in order to increase the reliability and accuracy of the wind measurements. The wind sensors measure the wind direction and wind speed.

The sensor is self-testing, and if the sensor signal is defective, the turbine will be brought to a safe condition.
To improve performance during icy conditions the sensors are equipped with a heating element.
The sensors are located on top of the nacelle and are protected against lightning strikes.

1.4.2.2 Smoke Detectors

The tower and nacelle are equipped with optical smoke sensors. If smoke is detected an alarm is sent via the RCS (Remote Control System) and the main switcher is activated. The detectors are self-controlling. If a detector becomes defective, a warning is sent via the RCS.

1.4.2.3 Lightning Detectors

Lightning detectors are located in each rotor blade.

1.4.2.4 Accelerometers

Accelerometers register the movements of the tower top. The registrations are intelligent-controlled by the VMP and used to remove unfavourable movements and vibrations.

1.4.2.5 GPS (Real Time Clock)

The GPS is primarily used to synchronise the turbine clock. The GPS accuracy is within 1 second. Via this system it is possible to compare the various log observations with other turbines within the same area/site. E.g. fluctuations in the power, grid or lightning activity.

1.4.2.6 Arc Protection

The transformer and the low voltage switchboards are protected by an arc protection system. In case of an electrical arc, the system will instantly open the main breaker downstream from the turbine.

1.5 Lightning Protection

The V90 Wind Turbine is equipped with Vestas Lightning Protection, which protects the entire turbine from the tip of the blades to the foundation. The system enables the lightning current to by-pass all vital components within the blade, nacelle and tower without causing damage. As an extra safety precaution, the control units and processors in the nacelle are protected by an efficient shielding system.

The lightning protection is designed according to IEC 61024 – "Lightning Protection of Wind Turbine Generators".

Lightning detectors are mounted on all three rotor blades. Data from the detectors are logged and enable the operator to identify which one of the blades that were hit, the exact time of the stroke, and how powerful the lightning was.
These data are very useful for making a remote estimate of possible damage to the turbine and the need for inspection.

1.6 Service

Service interval: 12 months

1.6.1 Lubrication of Components

- Blade bearings: Automatic lubrication from an electrically driven unit. Re-fill every 12 months.
- Generator bearings: Automatically lubricated via the gear oil system.
- Gearbox: The oil is collected in a tank. From the collection tank the oil is pumped to a heat exchanger and back to the gearbox. The pumps distribute the oil to the gear wheels and bearings.
- Yaw gear: lubrication in sealed oil bath, which is inspected every 12 months.
- Hydraulic system: The oil level is inspected every 12 months.

3. Micro Siting and Network Connection

3.1 Siting in Wind Farms

Often wind turbines are placed in wind farms where park introduced turbulence must be taken into account.

If the wind conditions of Section 4.2 and uniform wind rose apply, then the wind turbines can be sited in a wind farm with a distance of at least 5 rotor diameters (450 m) between the wind turbines.

If the wind turbines are placed in one row with the wind conditions of Section 4.2 and a uniform wind rose, then distance between the wind turbines should be at least 4 rotor diameters (360 m).

With above in mind, it is recommended that Vestas participate in the micro siting evaluation of the wind turbine.

3.2 Terrain Conditions

If the terrain is outside the below listed rules or the terrain otherwise seems complex, particular considerations may be necessary and Vestas must be contacted.

- Within a radius of 100 meters from the turbine, max. slope of 10°
- Within a radius of 100 to 500 meters from the turbine, max. slope of 15°
- Within a radius of 500 to 2000 meters radius from turbine, max. slope of 20°

3.3 Connection to the Electrical Power Grid

The transformer in the nacelle is manufactured to meet the nominal voltage of the interconnection grid (see Section 7.7 for acceptable grid voltage range without further transformation). The voltage of the medium voltage grid must be within +5/-5% of nominal voltage. Steady variations within +2/-3 Hz (60 Hz) are acceptable. Intermittent or rapid grid frequency fluctuations may cause serious damage to the turbine.
Averaged over the wind turbine's lifetime, grid failure must not occur more than once a week (e.g. maximum of 52 occurrences within a year).
A ground connection of maximum 10 Ω must be present.
The customer's grounding system must be designed for local soil conditions. The resistance to neutral ground must be in accordance with the requirements of the local authorities.

NB: When ordering, please provide VESTAS with precise information about grid voltage in order to facilitate specification of the transformer's nominal voltage and winding connection (delta connection on the medium voltage winding is supplied as default, unless otherwise specified). As an option, VESTAS offers medium voltage switchgear.

4. General Ambient Design Criteria

4.1 General Conditions

The wind turbine is designed for operation in ambient temperatures ranging from -20°C to +40°C. All components including liquids, oil etc. are designed to survive temperatures as low as -40°C. Special precautions must be taken outside these temperatures. If the temperature inside the nacelle exceeds 50°C, the turbine is paused.
The relative humidity can be 100 % (max. 10 % of the lifetime). Corrosion protection according to ISO 12944-2 or corrosion class C5M (outside) and C3 to C4 (inside). All corrosion protections are designed for long lifetime (more than 15 years). See special differentiation on tower in section 7.17 Tower.

4.2 Wind Conditions

The wind conditions can be described by a Weibull distribution where the annual average wind speed and a shape parameter describe the wind distribution. Further the wind climate can be described by maximum wind speeds and the turbulence. Turbulence is a factor to describe short-term wind variations/fluctuations. Below is listed the design conditions assumed for the operating environment for the Vestas V90-3.0 MW, 60 Hz wind turbine.

- Standard IEC IIA
- Average wind speed 8.5 m/s
- C-parameter 2
- Turbulence I_{15}*) 18%
- Max average wind **) 42.5 m/s
- Max wind gust ***) 59.5 m/s

*) The turbulence is wind dependent and varies from 34.1 – 16.1% at wind speeds between 4 - 25 m/s. At 15 m/s the turbulence is 18%
**) 10 min., 50 years' mean wind speed
***) 3 sec., 50 years' gust wind speed

Wind speed and turbulence refer to hub height.
The above listed wind conditions are design parameters as is the cut out wind speed. Other parameters can also influence the turbine lifetime and the following values should not be exceeded.

- Max wind gust acceleration 10 m/s^2
- Cut out Wind Speed 25 m/s
- Restart Wind Speed 20 m/s

5. Type Approvals

The V90 – 3.0 MW wind turbine will be type approved in accordance with:

- IEC WT01
- DS472
- NVN 11400-0
- DIBt Richtlinie für Windkraftanlagen
- SITAC

6. Options

6.1 Power Quality

The turbine is optionally equipped with a three-phase voltage- and current-measuring module.
The instrument transformers are located on the medium-voltage side, which afford the possibility to compensate the reactive power consumption in transformer and connection cables.

Based on measurements the following will be calculated:

- RMS active power
- RMS reactive power
- Phase angle (Cos Phi)
- Frequency
- Asymmetric ampere/voltage

From these calculations statistics are made on the power quality.

6.2 Medium Voltage Switch Gear

The purpose of the switch gear is to protect the turbine against over current, short circuit and ground faults. The switchgear consists of a gas-tight tank containing SF6 gas, a load-interrupter switch and a resettable fault interrupter, with visible open gaps (where required), integral visible grounds and a microprocessor-based overcurrent control. The load-breaker is also a 3-positioned breaker, which can earth the transformer cable through the circuit breaker. Load-interrupter switch terminals are equipped with bushings rated 600 amperes continuous, and fault-interrupter terminals that are equipped with bushing wells rated 200 amperes continuous or bushings rated 600 amperes continuous (as specified) to provide for elbow connection. Manual operating mechanisms and viewing windows are located to protect operating personnel from the bushings and bushing wells while performing any routine operations. A motor-operator is available for remote tripping of the switchgear, by the VMP controller, arc detector, smoke detector or manually from the nacelle.
Loop in and - out option is available.

6.3 Remote Control and Monitoring – VestasOnline™

The VestasOnline™ product family is the new generation of remote monitoring and control solutions from Vestas. It is based on field experience from the proven Vestas Remote Panel for Windows (WRPWin) and Vestas Graphical Control and Supervision (VGCS) programs. VestasOnline™ consists of three separate product packages:

VestasOnline™ Standard - designed for control and monitoring of single wind turbines and smaller wind power plants, typically consisting of up to 20 wind turbines.

VestasOnline™ Professional - designed for wind power plants that require additional functionality and flexibility as it includes a professional SQL database with capacity to store several years of wind power plant data. In addition, VestasOnline™ Professional also integrates and controls other wind power plant equipment such as substations, grid measurement stations, meteorological equipment and PLC systems. VestasOnline™ Professional is the recommended solution for single wind power plants consisting of up to 250 wind turbines.

VestasOnline™ Enterprise - is the high-end member of the product family. It contains all the features of VestasOnline™ Professional plus additional advanced software options for monitoring and managing multiple wind power plants.

VestasOnline™ Enterprise is the recommended solution for wind power plants consisting of up to 2000 wind turbines as well as for wind power plants with the highest demand for system availability.

6.4 Obstruction Light

At customer's request, Vestas is capable of delivering optional obstruction lighting for the V90 turbine. The turbine will be equipped with 2 obstruction lights on the nacelle, placed in such a manner that at least one light will always be visible.

The following standard integrated aviation light options are available:

1. Low intensity. Red 10-200 cd.
2. Medium intensity. Red/white/dual 200-2000 cd.
3. Medium intensity. Red/white/dual 2000 - 20000 cd.

The options are designed according to the ICAO- and the FAA codes.

When using obstruction light delivered by Vestas, a range of additional features are offered: Remote monitoring of light function, supervision of remaining lifetime, alarm if a lamp failure occurs and intensity control according to weather visibility and UPS. When installed in a wind farm, the obstruction light flash can be synchronized throughout the whole wind farm.

6.5 Service lift inside the tower

The turbine can be delivered with a UL/CSA approved service lift inside the tower.

6.6 Wind turbine color

Ral 9010 (white) and Ral 7035 (light grey) is available.

7. Technical Specifications & Diagrams

7.1 Rotor

Diameter:	90 m
Swept area:	6362 m^2
Speed, nominal power:	16.1 RPM Speed, Dynamic operation range
rotor:	9.9 - 18.4 RPM
Rotational direction:	Clockwise (front view)
Orientation:	Upwind
Tilt:	6°
Blade coning:	4°
Number of blades:	3
Aerodynamic brakes:	Full feathering

7.2 Hub

Type:	SG Cast Iron
Material:	GJS-400-18U-LT
Weight:	8500 kg

7.3 Blades

Principle:	Airfoil shells bonded to supporting beam
Material:	Fibreglass reinforced epoxy and carbon fibres
Blade connection:	Steel root inserts
Air foils:	RISØ P + FFA-W3
Length:	44 m
Chord at blade root:	3.512 m
Chord at blade tip:	0.391 m
Twist (blade root/blade tip):	17.5°

7.4 Bearings

Type:	4-point ball bearing

7.5 Sensors

7.5.1 Lightning Detector

Appellation:	Lightning detector
Signal:	Optical Analogue

7.5.2 Wind Sensor

Appellation:	Ultrasonic wind sensor, (2 units)
Signal:	RS485/optical

Accuracy:	+/- 0.1 m/s, less than 5 m/s +/- 2 %, more than 5 m/s

7.5.3 Smoke

Appellation:	Smoke detector
Signal:	Digital 24 V

7.5.4 Movements and Vibrations

Appellation:	Accelerometer, tower
Signal:	RS485

7.6 Generator

	Generator 60 Hz
Rated power:	3.0 MW
Type:	Asynchronous with wound rotor, slip rings and VCRS
Voltage:	1000 VAC
Frequency:	60 Hz
No. of poles:	4
Class of protection:	IP54
Rated speed:	1758
Rated power factor, default at 1000 V:	1.0
Power factor range at 1000 V:	0.98_{CAP} - 0.96_{IND}

7.7 Transformer

Type:	Cast resin
Rated Power:	3160 kVA
High voltage:	10 – 34.5 kV
Frequency:	60 Hz
Vector group:	Dyn
HV – Tappings:	±2 x 2.5%
Low voltage:	1000 V
Power at 1000 V:	3326 kVA
Low voltage:	400 V
Power at 400 V:	168 kVA

7.8 Switch Gear Electrical Characteristics

7.8.1 Feeder Function

Rated voltage [kV] (Max. system voltage)	27	38
Rated current [A]	600	600
Short time withstand current (1 or 3 s) [kA]	25	25
Insulation level:		
Power frequency (1 min) [kV]	50	50
Lightning impulse [kV_{peak}]	125	150
Making capacity [kA_{peak}]	40	40
Breaking capacity:		
Mainly active current [A]	600	600

7.8.2 Circuit Breaker Function

Rated voltage [kV] (Max. system voltage)	27	38
Rated current [A]	600	600
Short time withstand current (1 or 3 s) [kA]	25	25
Insulation level:		
Power frequency (1 min) [kV]	50	50
Lightning impulse [kV_{peak}]	125	150
Making capacity [kA_{peak}]	40	40
Breaking capacity [kA]	25	25

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:	4-step planetary gear with motor brake
Motor:	2.2 kW, 4 pole, asynchronous

7.11 Gearbox

Type:	2 planetary stage + 1 helical stage
Type no.:	EF901AE55-K1
Shaft distance:	461 mm
Ratio:	1:109.0 (60 Hz)

7.12 Parking Brake

Type:	PZ.I.4420.2802.10
Brake Pad type:	MPM 030
Supply:	Separate hydraulic pump unit

7.13 Hydraulics

Pressure:	250 bar
Placement:	The complete hydraulic system is mounted in the hub.

7.14 Cooling System

Gear oil cooling:	2 water/air cooling units located above the transformer room. Connected to the oil/water heat exchanger located by the gear oil tank.
Generator cooling:	2 water/air coolers located above the transformer room.
Water-cooling:	Coupled on generator cooler.
Transformer cooling:	Cooling air is blown through the windings from the bottom of the transformer.
Nacelle cooling:	Cooling of the nacelle is done by leading air through the glassfibre floor behind the tower. Outgoing air is led through a fan to the transformer room and is later blown out at the rear end of the nacelle. The air intake is controlled by a flap valve, which opens when the nacelle temperature reaches a certain level.

7.15 Nacelle Bedplate

Front part:	Spheroidal graphite iron GJS-400-18U-LT Foundation for gear, generator, yaw bedding, crane-girders and rear foundation.
Weight:	8500 kg
Rear part:	Welded gratings integrated with crane girders. Foundation for electrical panels, transformer and cooling room.

7.16 Nacelle

Material:	Fibreglass

7.17 Tower

Type:	Conical tubular
Material:	S355
Surface treatment:	Painted
Corosion class, outside:	C4 (ISO 12944-2)/offshore C5-M
Corosion class, inside:	C3 (ISO 12944-2)/offshore C4
Top diameter for all towers:	2.3 m
Bottom diameter for all towers:	3.98 m
	Hub Height
3-parted, modular tower	65 m
3-parted, modular tower	80 m

The exact hub height listed includes 0.55 m distance from the foundation section to the ground level and 2.0 m distance from the tower top flange to the hub center.

7.18 Weight and Dimensions

7.18.1 Nacelle

Including hub and nose cone:

Length:	13.25 m
Width:	3.6 m
Height:	4.05 m
Weight app.	88000 kg +/- 3000 kg

Without hub and nose cone:

Length:	9.65 m
Width:	3.6 m
Height:	4.05 m
Weight app.:	68000 kg +/- 2000 kg

7.18.2 Gearbox

Length: 2100 mm
Diameter: 2600 mm
Weight max.: 23000 kg

7.18.3 Generator

Length max.: 2800 mm
Diameter max.: 1100 mm
Weight max: 8500 kg

7.18.4 Transformer

Length: 2340 mm
Width: 1090 mm
Height: 2150 mm
Weight max.: 8000 kg

7.18.5 Rotor Blades

Length: 44 m
Weight .: 6600 kg/pcs +/- 400 kg.

7.18.6 Switch Gear, Feeder Function (Option)

Rated voltage [kV]	24	36
Width [mm]	370	420
Height [mm]	1400	1800
Depth [mm]	850	850
Weight [kg]	135	140

7.18.7 Switch Gear, Circuit Breaker Function (Option)

Rated voltage [Kv]	24	36
Width [mm]	480	600
Height [mm]	1400	1800
Depth [mm]	850	850
Weight [kg]	218	238

8. General Reservations, Notes and Disclaimers

- All data are valid at sea level (ρ=1.225 kg/m^3).
- 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.
- 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.

9. Performance Note

THE PERFORMANCE OF THE VESTAS V90-3.0 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 THESE GENERAL SPECIFICATIONS. MANY OF THESE VARIABLES INCLUDING, BUT NOT 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 THESE GENERAL SPECIFICATIONS 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 V90–3.0 MW WIND TURBINES, PLEASE CONTACT VESTAS DIRECTLY.

V100-2.75 & 3.0 MW
The future for low wind sites

Knowing the winds

The V100 knows which way the wind blows, and is designed to follow it. A significant advance in wind turbine efficiency, OptiSpeed®* allows the rotor speed to vary within a range of approximately 60 per cent in relation to nominal rpm. This means that with OptiSpeed®, the rotor speed can vary by as much as 30 per cent above and below synchronous speed. This means a five per cent improvement in the annual energy production.

But that is not all, OptiSpeed® technology provides several other advantages. For instance, the variable rotor speed reduces wear and tear on gearbox, blades and the tower itself. As an added benefit, the lower speed of rotation means an overall reduction in sound levels. Finally, OptiSpeed® technology supplies better quality power to the grid, with rapid synchronisation, reduced harmonic distortion and less flicker.

Blade technology

The 49-metre rotor blades of the V100 have a newly developed blade profile with improved aerodynamics. A new plane shape and a curved back edge improve energy generation, while simultaneously making the leading edge of the blade profile less sensitive to dirt and maintaining a favourable geometrical relationship between successive airfoil thicknesses.

This translates into to an increase in output and a decrease in load transfers – which results in an improved bottom line.

Easy service and maintenance

Vestas is constantly working to reducing the need for service and maintenance of its wind turbines and, at the same time, to ensure that service visits can be performed as effortlessly as possible. In the V100 turbine, access has become easier and the working areas have been expanded. The arrangement of tower and nacelle components has also been optimised to facilitate service procedures.

Together with a series of new features ranging from automatic blade-bearing lubrication to an oil-lubricated yaw system, this means considerable savings in turbine downtime and personnel costs. In fact, as a result of these improvements, the V100 only needs one service visit per year.

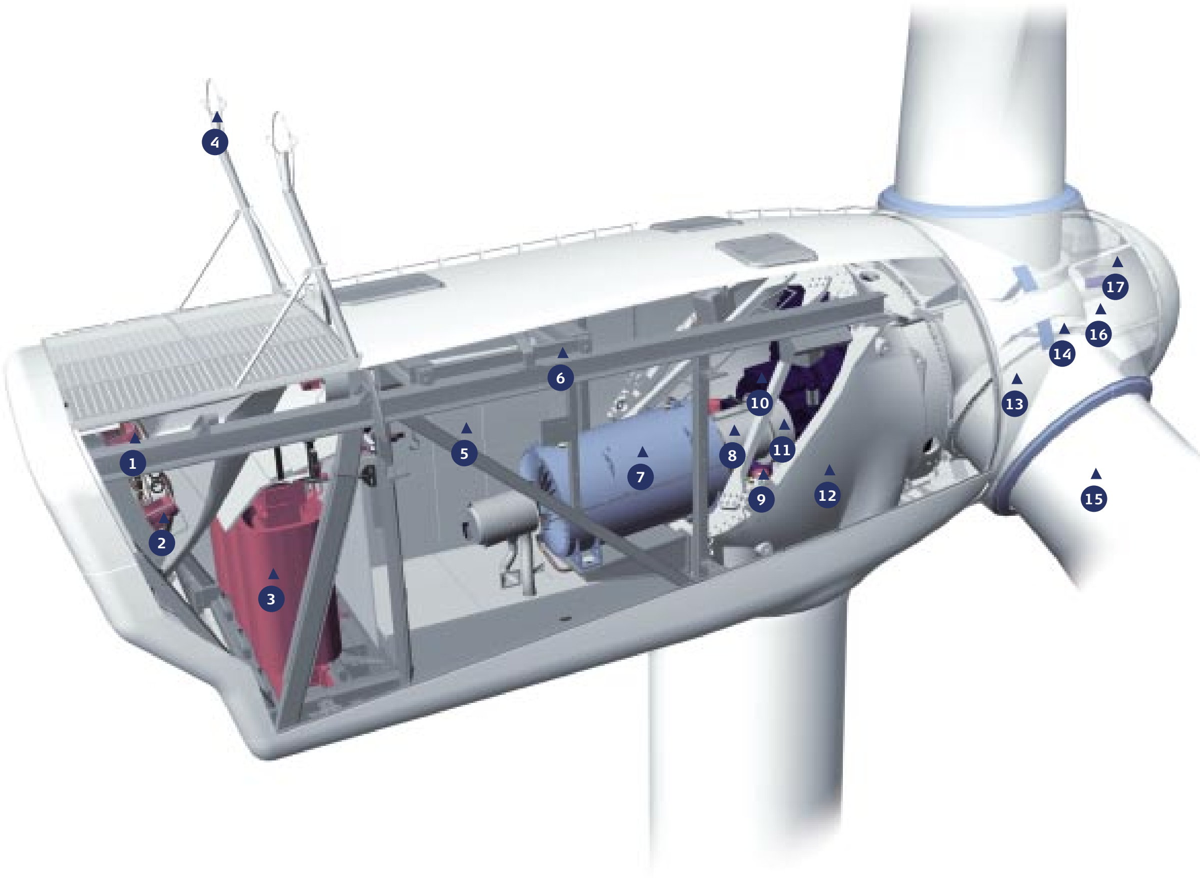
Proven performance

Wind power plants require substantial investments, and the process can be very complex. To assist in the evaluation and purchasing process, Vestas has identified four factors that are critical to wind turbine quality: energy production, operational availability, power quality and sound level.

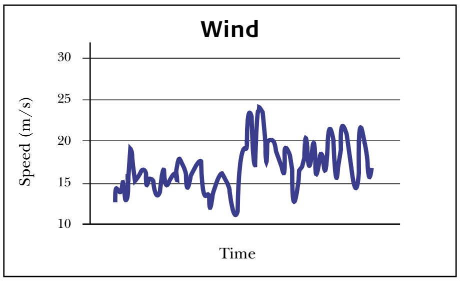
We spend months testing and documenting these performance areas for all Vestas turbines. When we are finally satisfied, we ask an independent testing organisation to verify the results – a practice we call Proven Performance. At Vestas we do not just talk about quality. We prove it.

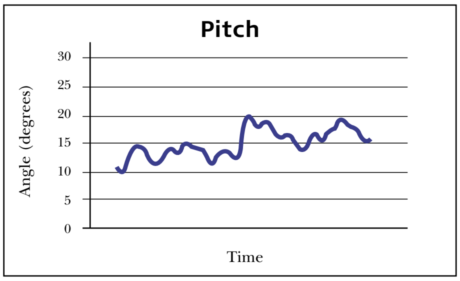
* Vestas OptiSpeed® is not available in the USA and Canada.

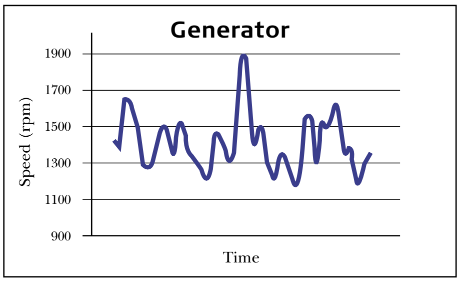
Technical specifications

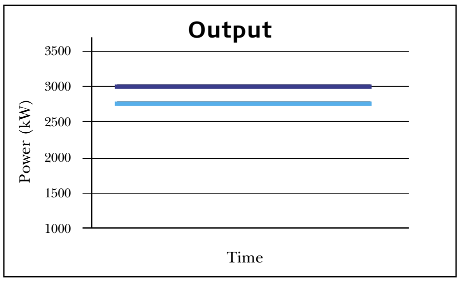


1. Oil cooler
2. Water cooler for generator
3. High voltage transformer
4. Ultrasonic wind sensors
5. VMP-Top controller with converter
6. Service crane
7. OptiSpeed® generator
8. Composite disc coupling
9. Yaw gears
10. Gearbox
11. Mechanical disc brake
12. Machine foundation
13. Blade bearing
14. Blade hub
15. Blade
16. Pitch cylinder
17. Hub controller









OptiSpeed® allows the rotor speed to vary within a range of approximately 60 per cent in relation to nominal rpm. Thus with OptiSpeed®, the rotor speed can vary by as much as 30 per cent above and below synchronous speed. This minimises both unwanted fluctuations in the output to the grid supply and the loads on the vital parts of the construction.

Rotor

Diameter:	100 m
Area swept:	7,850 m²
Nominal revolutions:	13.4 rpm
Operational interval:	7.2-15.3 rpm
Number of blades:	3
Power regulation:	Pitch/OptiSpeed®
Air brake:	Full blade pitch by 3 separate pitch cylinders

Tower

Hub height:	80 m, 100 m

Operational data

	IEC IIA: 2.75 MW	IEC IIIA: 3.0 MW
Cut-in wind speed:	4 m/s	4 m/s
Nominal wind speed:	15 m/s	16 m/s
Cut-out wind speed:	25 m/s	25 m/s

Generator

	IEC IIA:	IEC IIIA:
Type:	Asynchronous with OptiSpeed®	Asynchronous with OptiSpeed®
Nominal output:	2.75 MW	3.0 MW
Operational data:	50 Hz 1000 V	50 Hz 1000 V

Gearbox

Type:	Two planetary and one helical stage

Control

Type:	Microprocessor-based control of all the turbine functions with the option of remote monitoring and control. Output regulation and optimisation via OptiSpeed® and OptiTip® pitch regulation.

Weight

	IEC IIA:	IEC IIIA:
Hub height:	80 m	100 m
Tower:	156 t	236 t
Nacelle:	66 t	66 t
Rotor:	42 t	42 t
Total:	264 t	344 t

t = metric tonnes

All specifications subject to change without notice.

The future for low wind sites

With the new V100-2.75 & 3.0 MW Vestas is focusing on highly efficient onshore turbines for sites with low to medium wind speeds. The V100 turbine represents a further development of the V90-3.0 MW turbine that has already proven its worth. Differences from the V90 include longer rotor blades and another gear ratio for optimising power output in areas with low winds.

The numerous innovations introduced with the V90 turbine are of course also to be found in the V100 – including the individual pitch system that allows precise, individual adjustment of the angle of each rotor blade in relation to the prevailing wind conditions. This innovative pitch system reduces the loads on the vital components and thus improves the overall economy.

From materials and production, through transportation, to the actual erection of the turbine, weight is one of the most critical cost factors. Over the years, Vestas has succeeded in reducing weight appreciably in almost all areas of its turbines. This tradition has been continued in the V100, which is designed for optimal load distribution, has lighter blades and features an innovative nacelle design with a built-in transport system. As a result, the V100 is easier to transport than any other turbine in this class.

Vestas Wind Systems A/S
Alsvej 21
8900 Randers
Denmark
Tel. +45 97 30 00 00
Fax +45 97 30 00 01
vestas@vestas.com
www.vestas.com

To see a complete list of our
sales and service units, visit
www.vestas.com

12/04