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General Description

3MW Platform

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1 Introduction

The 3MW Platform wind turbine configurations covered by this General Description are listed below with designations according to IEC61400-22.

The maximum DIBt 2012 wind class is listed where applicable.

Please refer to the Performance Specification for the relevant turbine variant for full wind class definition.

This General Description contains data and descriptions common among the platform variants.

The variant specific performance can be found in the Performance Specifications for the turbine variant and operational mode required.

Turbine Type Class	Turbine Type | Operating Mode
V105-3.45 MW	V105-3.45 MW IEC IA 50/60 Hz | Mode 0
	V105-3.45 MW IEC IA 50/60 Hz | Reactive Power Optimized Mode (QO1)
	V105-3.6 MW IEC IA 50/60 Hz | Power Optimized Mode (PO1)
	V105-3.55 MW IEC IA 50/60 Hz | Power Optimized Mode (PO2)
	V105-3.5 MW IEC IA 50/60 Hz | Power Optimized Mode (PO3)
	V105-3.3 MW IEC IA 50/60 Hz | Load Optimized Mode (LO1)
	V105-3.0 MW IEC IA 50/60 Hz | Load Optimized Mode (LO2)
V112-3.45 MW	V112-3.45 MW IEC IA 50/60 H0z | Mode 0
	V112-3.45 MW IEC IA 50/60 Hz | Reactive Power Optimized Mode (QO1)
	V112-3.6 MW IEC IA 50/60 Hz | Power Optimized Mode (PO1)
	V112-3.55 MW IEC IA 50/60 Hz | Power Optimized Mode (PO2)
	V112-3.5 MW IEC IA 50/60 Hz | Power Optimized Mode (PO3)
	V112-3.3 MW IEC IA 50/60 Hz | Load Optimized Mode (LO1)
	V112-3.0 MW IEC IA 50/60 Hz | Load Optimized Mode (LO2)
V117-3.45 MW	V117-3.45 MW IEC IB + IIA 50/60 Hz | Mode 0
	V117-3.45 MW IEC IB + IIA 50/60 Hz | Reactive Power Optimized Mode (QO1)
	V117-3.6 MW IEC S + IIA 50/60 Hz | Power Optimized Mode (PO1)
	V117-3.55 MW IEC S + IIA 50/60 Hz | Power Optimized Mode (PO2)
	V117-3.5 MW IEC S + IIA 50/60 Hz | Power Optimized Mode (PO3)
	V117-3.3 MW IEC IB + IIA 50/60 Hz | Load Optimized Mode (LO1)
	V117-3.0 MW IEC IB + IIA 50/60 Hz | Load Optimized Mode (LO2)
V126-3.45 MW Low Torque (LTq)	V126-3.45 MW IEC IIB + IIIA 50/60 Hz LTq | Mode 0
	V126-3.45 MW IEC IIB + IIIA 50/60 Hz LTq | Reactive Power Optimized Mode (QO1)
	V126-3.3 MW IEC IIB + IIIA 50/60 Hz LTq | Load Optimized Mode (LO1)
	V126-3.0 MW IEC IIB + IIIA 50/60 Hz LTq | Load Optimized Mode (LO2)

Turbine Type Class	Turbine Type | Operating Mode
V126-3.45 MW High Torque (HTq)	V126-3.45 MW IEC IIA + IIIA 50/60 Hz HTq | Mode 0
	V126-3.45 MW IEC IIA + IIIA 50/60 Hz HTq | Reactive Power Optimized Mode (QO1)
	V126-3.6 MW IEC IIA + IIIA 50/60 Hz HTq | Power Optimized Mode (PO1)
	V126-3.55 MW IEC IIA + IIIA 50/60 Hz HTq | Power Optimized Mode (PO2)
	V126-3.5 MW IEC IIA + IIIA 50/60 Hz HTq | Power Optimized Mode (PO3)
	V126-3.3 MW IEC IIA + IIIA 50/60 Hz HTq | Load Optimized Mode (LO1)
	V126-3.0 MW IEC IIA + IIIA 50/60 Hz HTq | Load Optimized Mode (LO2)
	V126-3.45 MW WZ 3 GK II TK A 50 Hz HTq | Mode 0
	V126-3.45 MW WZ 3 GK II TK A 50 Hz HTq | Reactive Power Optim. Mode (QO1)
	V126-3.6 MW WZ 3 GK II TK A 50 Hz HTq | Power Optimized Mode (PO1)
	V126-3.55 MW WZ 3 GK II TK A 50 Hz HTq | Power Optimized Mode (PO2)
	V126-3.5 MW WZ 3 GK II TK A 50 Hz HTq | Power Optimized Mode (PO3)
V136-3.45 MW	V136-3.45 MW IEC IIB + IIIA 50/60 Hz | Mode 0
	V136-3.45 MW IEC IIB + IIIA 50/60 Hz | Reactive Power Optimized Mode (QO1)
	V136-3.6 MW IEC S + IIIA 50/60 Hz | Power Optimized Mode (PO1)
	V136-3.55 MW IEC S + IIIA 50/60 Hz | Power Optimized Mode (PO2)
	V136-3.5 MW IEC S + IIIA 50/60 Hz | Power Optimized Mode (PO3)
	V136-3.3 MW IEC IIIA 50/60 Hz | Load Optimized Mode (LO1)
	V136-3.0 MW IEC IIIA 50/60 Hz | Load Optimized Mode (LO2)
	V136-3.45 MW WZ 2 GK II TK A 50 Hz | Mode 0
	V136-3.45 MW WZ 2 GK II TK A 50 Hz | Reactive Power Optimized Mode (QO1)
	V136-3.6 MW WZ 2 GK II TK A 50 Hz | Power Optimized Mode (PO1)
	V136-3.55 MW WZ 2 GK II TK A 50 Hz | Power Optimized Mode (PO2)
	V136-3.5 MW WZ 2 GK II TK A 50 Hz | Power Optimized Mode (PO3)

Table 1-1: 3MW Platform turbine configurations covered.

2 General Description

Vestas 3MW Platform comprises a family of wind turbines sharing a common design basis.

The 3MW Platform family of wind turbines includes V105-3.45 MW, V112-3.45 MW, V117-3.45 MW, V126-3.45 MW and V136-3.45 MW.

These turbines are pitch regulated upwind turbines with active yaw and a three-blade rotor.

The wind turbine family provides rotors with a diameter in the range 105 m to 136 m and a rated output power of 3.45 MW.

A 3.45 MW Reactive Power Optimized Mode (QO1) is available for all variants.

A 3.6 MW Power Optimized Mode (PO1), a 3.55 MW Power Optimized Mode (PO2) and a 3.5 MW Power Optimized Mode (PO3) are available for all variants except V126-3.45 MW Low Torque (LTq).

Also, a 3.3 MW Load Optimized Mode (LO1) and a 3.0 MW Load Optimized Mode (LO2) are available for all variants.

The wind turbine family utilises the OptiTip® concept and a power system based on an induction generator and full-scale converter. With these features, the wind turbine is able to operate the rotor at variable speed and thereby maintain the power output at or near rated power even in high wind speed. At low wind speed, the OptiTip® concept and the power system work together to maximise the power output by operating at the optimal rotor speed and pitch angle.

Operating the wind turbine in the 3.45 MW Reactive Power Optimized Mode (QO1) is achieved by applying an extended ambient temperature derate strategy compared with 3.45 MW Mode 0 operation.

Operating the wind turbine in Power Optimized Mode (PO1-PO3) is achieved by applying an extended ambient temperature derate strategy and reduced reactive power capability compared with 3.45 MW Mode 0 operation.

3 Mechanical Design

3.1 Rotor

The wind turbine is equipped with a rotor consisting of three blades and a hub. The blades are controlled by the microprocessor pitch control system OptiTip®. Based on the prevailing wind conditions, the blades are continuously positioned to optimise the pitch angle.

Rotor	V105	V112	V117	V126	V136
Diameter	105 m	112 m	117 m	126 m	136 m
Swept Area	8659 m^2	9852 m^2	10751 m^2	12469 m^2	14527 m^2
Speed, Dynamic Operation Range	8.3-17.6	8.1-17.6	6.7-17.6	HTq: 5.9-16.0 LTq: 6.2-16.0	HH>82: 5.6-14.0 HH=82: 6.9-14.0
Rotational Direction	Clockwise (front view)				
Orientation	Upwind				
Tilt	6°				
Hub Coning	4°				
No. of Blades	3				
Aerodynamic Brakes	Full feathering				

Table 3-1: Rotor data.

3.2 Blades

The blades are made of carbon and fibreglass and consist of two airfoil shells bonded to a supporting beam.

Blades	V105	V112	V117	V126	V136
Type Description	Airfoil shells bonded to supporting beam			Infused structural airfoil shell	
Blade Length	51.15 m	54.65 m	57.15 m	61.66 m	66.66 m
Material	Fibreglass reinforced epoxy, carbon fibres and Solid Metal Tip (SMT).				
Blade Connection	Steel roots inserted				
Airfoils	High-lift profile				
Maximum Chord	4.0 m				4.1 m

Table 3-2: Blades data.

3.3 Blade Bearing

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

Blade Bearing	
Lubrication	Grease

Table 3-3: Blade bearing data.

3.4 Pitch System

The turbine is equipped with a pitch system for each blade and a distributor block, all located in the hub. Each pitch system is connected to the distributor block with flexible hoses. The distributor block is connected to the pipes of the hydraulic rotating transfer unit in the hub by means of three hoses (pressure line, return line and drain line).

Each pitch system consists of a hydraulic cylinder mounted to the hub and a piston rod mounted to the blade bearing via a torque arm shaft. Valves facilitating operation of the pitch cylinder are installed on a pitch block bolted directly onto the cylinder.

Pitch System	
Type	Hydraulic
Number	1 per blade
Range	-10° to 90°

Table 3-4: Pitch system data.

Hydraulic System	
Main Pump	Two redundant internal-gear oil pumps

Hydraulic System	
Pressure	260 bar
Filtration	3 µm (absolute)

Table 3-5: Hydraulic system data.

3.5 Hub

The hub supports the three blades and transfers the reaction loads to the main bearing and the torque to the gearbox. The hub structure also supports blade bearings and pitch cylinders.

Hub	
Type	Cast ball shell hub
Material	Cast iron

Table 3-6: Hub data.

3.6 Main Shaft

The main shaft transfers the reaction forces to the main bearing and the torque to the gearbox.

Main Shaft	
Type Description	Hollow shaft
Material	Cast iron

Table 3-7: Main shaft data.

3.7 Main Bearing Housing

The main bearing housing covers the main bearing and is the first connection point for the drive train system to the bedplate.

Main Bearing Housing	
Material	Cast iron

Table 3-8: Main bearing housing data.

3.8 Main Bearing

The main bearing carries all thrust loads.

Main Bearing	
Type	Double-row spherical roller bearing
Lubrication	Automatic grease lubrication

Table 3-9: Main bearing data.

3.9 Gearbox

The main gear converts the low-speed rotation of the rotor to high-speed generator rotation.

The disc brake is mounted on the high-speed shaft. The gearbox lubrication system is a pressure-fed system.

Gearbox	
Type	Planetary stages + one helical stage
Gear House Material	Cast
Lubrication System	Pressure oil lubrication
Backup Lubrication System	Oil sump filled from external gravity tank
Total Gear Oil Volume	1000-1200
Oil Cleanliness Codes	ISO 4406-/15/12
Shaft Seals	Labyrinth

Table 3-10: Gearbox data.

3.10 Generator Bearings

The bearings are grease lubricated and grease is supplied continuously from an automatic lubrication unit.

3.11 High-Speed Shaft Coupling

The coupling transmits the torque of the gearbox high-speed output shaft to the generator input shaft.

The coupling consists of two 4-link laminate packages and a fibreglass intermediate tube with two metal flanges.

The coupling is fitted to two-armed hubs on the brake disc and the generator hub.

3.12 Yaw System

The yaw system is an active system based on a robust pre-tensioned plain yaw-bearing concept with PETP as friction material.

Yaw System	
Type	Plain bearing system
Material	Forged yaw ring heat-treated. Plain bearings PETP
Yawing Speed (50 Hz)	0.45°/sec.
Yawing Speed (60 Hz)	0.55°/sec.

Table 3-11: Yaw system data.

Yaw Gear	
Type	Multiple stages geared
Ratio Total	944:1

Yaw Gear	
Rotational Speed at Full Load	1.4 rpm at output shaft

Table 3-12: Yaw gear data.

3.13 Crane

The nacelle houses the internal safe working load (SWL) service crane. The crane is a single system hoist.

Crane	
Lifting Capacity	Maximum 800 kg

Table 3-13: Crane data.

3.14 Towers

Tubular towers with flange connections, certified according to relevant type approvals, are available in different standard heights. The towers are designed with the majority of internal welded connections replaced by magnet supports to create a predominantly smooth-walled tower.

Magnets provide load support in a horizontal direction and internals, such as platforms, ladders, etc., are supported vertically (that is, in the gravitational direction) by a mechanical connection. The smooth tower design reduces the required steel thickness, rendering the tower lighter compared to one with all internals welded to the tower shells.

Available hub heights are listed in the Performance Specification for each turbine variant. Designated hub heights include a distance from the foundation section to the ground level of approximately 0.2 m depending on the thickness of the bottom flange and a distance from tower top flange to centre of the hub of 2.2 m.

Towers	
Type	Cylindrical/conical tubular

Table 3-14: Tower structure data.

3.15 Nacelle Bedplate and Cover

The nacelle cover is made of fibreglass. Hatches are positioned in the floor for lowering or hoisting equipment to the nacelle and evacuation of personnel. The roof section is equipped with wind sensors and skylights.

The skylights can be opened from inside the nacelle to access the roof and from outside to access the nacelle. Access from the tower to the nacelle is through the yaw system.

The nacelle bedplate is in two parts and consists of a cast iron front part and a girder structure rear part. The front of the nacelle bedplate is the foundation for the drive train and transmits forces from the rotor to the tower through the yaw system. The bottom surface is machined and connected to the yaw bearing and the yaw gears are bolted to the front nacelle bedplate.

The crane girders 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, the cooling system and transformer. The nacelle cover is installed on the nacelle bedplate.

Type Description	Material
Nacelle Cover	GRP
Bedplate Front	Cast iron
Bedplate Rear	Girder structure

Table 3-15: Nacelle bedplate and cover data.

3.16 Thermal Conditioning System

The thermal conditioning system consists of a few robust components:

- The Vestas CoolerTop® located on top of the rear end of the nacelle. The CoolerTop® is a free flow cooler, thus ensuring that there are no electrical components in the thermal conditioning system located outside the nacelle.
- The Liquid Cooling System, which serves the gearbox, hydraulic systems, generator and converter is driven by an electrical pumping system.
- The transformer forced air cooling comprised of an electrical fan.

3.16.1 Generator and Converter Cooling

The generator and converter cooling systems operate in parallel. A dynamic flow valve mounted in the generator cooling circuit divides the cooling liquid flow. The cooling liquid removes heat from the generator and converter unit using a free-air flow radiator placed on the top of the nacelle. In addition to the generator, converter unit and radiator, the circulation system includes an electrical pump and a three-way thermostatic valve.

3.16.2 Gearbox and Hydraulic Cooling

The gearbox and hydraulic cooling systems are coupled in parallel. A dynamic flow valve mounted in the gearbox cooling circuit divides the cooling flow. The cooling liquid removes heat from the gearbox and the hydraulic power unit through heat exchangers and a free-air flow radiator placed on the top of the nacelle. In addition to the heat exchangers and the radiator, the circulation system includes an electrical pump and a three-way thermostatic valve.

3.16.3 Transformer Cooling

The transformer is equipped with forced-air cooling. The ventilator system consists of a central fan, located below the converter and an air duct leading the air to locations beneath and between the high voltage and low voltage windings of the transformer.

3.16.4 Nacelle Cooling

Hot air generated by mechanical and electrical equipment is dissipated from the nacelle by a fan system located in the nacelle.

3.16.5 Optional Air Intake Hatches

Specific air intakes in the nacelle can optionally be fitted with hatches which can be operated as a part of the thermal control strategy. In case of lost grid to the turbine, the hatches will automatically be closed.

4 Electrical Design

4.1 Generator

The generator is a three-phase asynchronous induction generator with cage rotor that is connected to the grid through a full-scale converter. The generator housing allows the circulation of cooling air within the stator and rotor. The air-to-water heat exchange occurs in an external heat exchanger.

Generator	
Type	Asynchronous with cage rotor
Rated Power [P_N]	3650 kW / 3800 kW
Frequency [f_N]	0-100 Hz
Voltage, Stator [U_{NS}]	3 x 750 V (at rated speed)
Number of Poles	4/6
Winding Type	Form with VPI (Vacuum Pressurized Impregnation)
Winding Connection	Star or Delta
Rated rpm	1450-1550 rpm
Overspeed Limit Acc. to IEC (2 minutes)	2400 rpm
Generator Bearing	Hybrid/ceramic
Temperature Sensors, Stator	3 PT100 sensors placed at hot spots and 3 as back-up
Temperature Sensors, Bearings	1 per bearing
Insulation Class	F or H
Enclosure	IP54

Table 4-1: Generator data.

4.2 Converter

The converter is a full-scale converter system controlling both the generator and the power quality delivered to the grid. The converter consists of 3 machine-side converter units and 3 line-side converter units operating in parallel with a common controller.

The converter controls conversion of variable frequency AC power from the generator into fixed frequency AC power with desired active and reactive power levels (and other grid connection parameters) suitable for the grid.

The converter is located in the nacelle and has a grid side voltage rating of 650 V. The generator side voltage rating is up to 750 V dependent on generator speed.

Converter	
Rated Apparent Power [S_N]	4400 kVA
Rated Grid Voltage	3 x 650 V
Rated Generator Voltage	3 x 750 V
Rated Grid Current	3900 A (≤30°C ambient) / 3950 (≤20°C ambient)
Rated Generator Current	3400 A (≤30°C ambient) / 3450 (≤20°C ambient)
Enclosure	IP54

Table 4-2: Converter data.

4.3 HV Transformer

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

The transformer comes in different versions depending on the market where it is intended to be installed.

- For 50 Hz regions the transformer is as default designed according to IEC standards. However, on special request, a 60 Hz transformer based on IEC standards could also be delivered. Refer to Table 4-3.
- For turbines installed in Member States of the European Union, it is required to fulfil the Ecodesign regulation No 548/2014 set by the European Commission. Refer to Table 4-4.
- For 60 Hz regions the transformer is as default designed mainly according to IEEE standards but on areas not covered by IEEE standards, the design is also based on parts of the IEC standards. Refer to Table 4-5.

4.3.1 IEC 50 Hz/60 Hz version

Transformer	
Type description	Dry-type cast resin transformer.
Basic layout	3 phase, 2 winding transformer.
Applied standards	IEC 60076-11, IEC 60076-16, IEC 61936-1.
Cooling method	AF
Rated power	4000 kVA
Rated voltage, turbine side	
U_m 1.1kV	0.650 kV
Rated voltage, grid side	
U_m 12.0kV	10.0-11.0 kV
U_m 24.0kV	11.1-22.0 kV
U_m 36.0kV	22.1-33.0 kV
U_m 40.5kV	33.1-36.0 kV
Insulation level AC / LI / LIC	

Transformer			
U_m 1.1kV	3[1] / - / - kV		
U_m 12.0kV	28[1] / 75 / 75 kV		
U_m 24.0kV	50[1] / 125 / 125 kV		
U_m 36.0kV	70[1] / 170 / 170 kV		
U_m 40.5kV	80[1] / 170 / 170 kV		
Off-circuit tap changer	±2 x 2.5 %		
Frequency	50 Hz / 60Hz		
Vector group	Dyn5		
No-load loss [3]			
U_m 12.0kV	7.5 kW		
U_m 24.0kV	7.5 kW		
U_m 36.0kV	7.5 kW		
U_m 40.5kV	7.5 kW		
Load loss @ power consumption HV, 120°C	**@4000kVA[3]**	**@3600kVA[5]**	**@3450kVA[5]**
U_m 12.0kV	31.8 kW	25.8kW	23.7kW
U_m 24.0kV	31.8 kW	25.8kW	23.7kW
U_m 36.0kV	31.8 kW	25.8kW	23.7kW
U_m 40.5kV	31.8 kW	25.8kW	23.7kW
No-load reactive power [2]	~29 kVAr		
Full load reactive power [2]	~387 kVAr		
No-load current [2]	~0.5 %		
Positive sequence short-circuit impedance@ rated power, 120°C [3]	9.0 %		
Positive sequence short-circuit resistance@ rated power, 120°C [2]	~0.8 %		
Zero sequence short-circuit impedance@ rated power, 120°C [2]	~8.5 %		
Zero sequence short-circuit resistance@ rated power, 120°C [2]	~0.8 %		
Inrush peak current [2]			
Dyn5	5-8 x $\hat{I}_n$		
YNyn0	8-12 x $\hat{I}_n$		
Half crest time [2]	~0.6 s		
Sound power level	≤ 80 dB(A)		
Average temperature rise at max altitude	≤90 K		
Max altitude [4]	2000 m		
Insulation class	155 (F)		
Environmental class	E2		
Climatic class	C2		
Fire behaviour class	F1		
Corrosion class	C4		
Weight	≤9500 kg		
Temperature monitoring	PT100 sensors in LV windings and core		
Overvoltage protection	Surge arresters on HV terminals		
Temporary earthing	3 x Ø20 mm earthing ball points		

Table 4-3: Transformer data for IEC 50 Hz/60 Hz version

NOTE

[1] @1000m. According to IEC 60076-11, AC test voltage is altitude dependent.
[2] Based on an average of calculated values across voltages and manufacturers.
[3] Subjected to standard IEC tolerances.
[4] Transformer max altitude may be adjusted to match turbine location.
[5] Information values based on operation mode, see See Figure 4-1.

4.3.2 Ecodesign - IEC 50 Hz/60 Hz version

Transformer			
Type description	Ecodesign dry-type cast resin transformer.		
Basic layout	3 phase, 2 winding transformer.		
Applied standards	IEC 60076-11, IEC 60076-16, IEC 61936-1, Commission Regulation No 548/2014.		
Cooling method	AF		
Rated power	4000 kVA		
Rated voltage, turbine side			
U_m 1.1kV	0.650 kV		
Rated voltage, grid side			
U_m 12.0kV	10.0-11.0 kV		
U_m 24.0kV	11.1-22.0 kV		
U_m 36.0kV	22.1-33.0 kV		
U_m 40.5kV	33.1-36.0 kV		
Insulation level AC / LI / LIC			
U_m 1.1kV	3[1] / - / - kV		
U_m 12.0kV	28[1] / 75 / 75 kV		
U_m 24.0kV	50[1] / 125 / 125 kV		
U_m 36.0kV	70[1] / 170 / 170 kV		
U_m 40.5kV	80[1] / 170 / 170 kV		
Off-circuit tap changer	±2 x 2.5 %		
Frequency	50 Hz / 60 Hz		
Vector group	Dyn5		
Peak Efficiency Index (PEI) [2]	Ecodesign requirement		
U_m 12.0kV	> 99.348		
U_m 24.0kV	> 99.348		
U_m 36.0kV	> 99.348		
U_m 40.5kV	> 99.158		
No-load loss [2]			
U_m 12.0kV	< 5.8 kW		
U_m 24.0kV	< 5.8 kW		
U_m 36.0kV	< 5.8 kW		
U_m 40.5kV	< 6.9 kW		
Load loss @ power consumption HV, 120°C	**@4000kVA[2]**	**@3600kVA[6]**	**@3450kVA[6]**
U_m 12.0kV	< 29.3 kW	< 23.8 kW	< 21.8 kW
U_m 24.0kV	< 29.3 kW	< 23.8 kW	< 21.8 kW
U_m 36.0kV	< 29.3 kW	< 23.8 kW	< 21.8 kW
U_m 40.5kV	< 37.85 kW	< 30.7 kW	< 28.2 kW
No-load reactive power [3]	~17 kVAr		
Full load reactive power [3]	~379 kVAr		
No-load current [3]	~0.5 %		
Positive sequence short-circuit	9.0 %		

Transformer	
impedance@ rated power, 120°C [4]	
Positive sequence short-circuit resistance@ rated power, 120°C [3]	~0.8 %
Zero sequence short-circuit impedance@ rated power, 120°C [3]	~8.2 %
Zero sequence short-circuit resistance@ rated power, 120°C [3]	~0.7 %
Inrush peak current [3]	
Dyn5	5-8 x $\hat{I}_n$
YNyn0	8-12 x $\hat{I}_n$
Half crest time [3]	~ 0.6 s
Sound power level	≤ 80 dB(A)
Average temperature rise at max altitude	≤90 K
Max altitude [5]	2000 m
Insulation class	155 (F)
Environmental class	E2
Climatic class	C2
Fire behaviour class	F1
Corrosion class	C4
Weight	≤9500 kg
Temperature monitoring	PT100 sensors in LV windings and core
Overvoltage protection	Surge arresters on HV terminals
Temporary earthing	3 x Ø20 mm earthing ball points

Table 4-4: Transformer data for Ecodesign IEC 50 Hz/60 Hz version.

NOTE

[1] @1000m. According to IEC 60076-11, AC test voltage is altitude dependent.
[2] For Ecodesign transformers, PEI is the legal requirement and is calculated according to the Commission Regulation based on rated power, no-load and load losses. Losses are maximum values and will not simultaneously occur in a specific design as this will be incompliant with the PEI requirement.
[3] Based on an average of calculated values across voltages and manufacturers.
[4] Subjected to standard IEC tolerances.
[5] Transformer max altitude may be adjusted to match turbine location.
[6] Information values based on operation mode, see Figure 4-1.

4.3.3 IEEE 60Hz version

Transformer	
Type description	Dry-type cast resin transformer.
Basic layout	3 phase, 2 winding transformer.
Applied standards	UL 1562, CSA C22.2 No. 47, IEEE C57.12, IEC 60076-11, IEC 60076-16, IEC 61936-1.
Cooling method	AFA
Rated power	4000 kVA
Rated voltage, turbine side	
N_{LL} 1.2 kV	0.650 kV
Rated voltage, grid side	
N_{LL} 15.0 kV	10.0-15.0 kV

Transformer			
N_{LL} 25.0 kV	15.1-25.0 kV		
N_{LL} 34.5 kV	25.1-34.5 kV		
Insulation level AC / LI & LIC			
N_{LL} 1.2 kV	4[1] / +10 kV		
N_{LL} 15.0 kV	34[1] / +95 kV		
N_{LL} 25.0 kV	50[1] / +125 kV		
N_{LL} 34.5 kV	70[1] / (+150 & -170) or +170 kV		
Off-circuit tap changer	±2 x 2.5 %		
Frequency	60 Hz		
Vector group	Dyn5		
No-load loss [3]	7.5 kW		
Load loss @ power consumption HV, 120°C	@4000kVA[3]	@3600kVA[5]	@3450kVA[5]
N_{LL} 15.0 kV	31.9 kW	25.9 kW	23.8 kW
N_{LL} 25.0 kV	31.9 kW	25.9 kW	23.8 kW
N_{LL} 34.5 kV	31.9 kW	25.9 kW	23.8 kW
No-load reactive power [2]	~16 kVAr		
Full load reactive power [2]	~345 kVAr		
No-load current [2]	~0.5 %		
Positive sequence short-circuit impedance@ rated power, 120°C [3]	~9.0 %		
Positive sequence short-circuit resistance@ rated power, 120°C [2]	~0.8 %		
Zero sequence short-circuit impedance@ rated power, 120°C [2]	~8.3 %		
Zero sequence short-circuit resistance@ rated power, 120°C [2]	~0.7 %		
Inrush peak current [2]			
Dyn5	6-9 x $\hat{I}_n$		
YNyn0	8-12 x $\hat{I}_n$		
Half crest time [2]	~ 0.7 s		
Sound power level	≤ 80 dB(A)		
Average temperature rise at max altitude	≤ 90 K		
Max altitude [4]	2000 m		
Insulation class	150°C		
Environmental class	E2		
Climatic class	C2		
Fire behaviour class	F1		
Corrosion class	C4		
Weight	≤ 9500 kg		
Temperature monitoring	PT100 sensors in LV windings and core		
Overvoltage protection	Surge arresters on HV terminals		
Temporary earthing	3 x Ø20 mm earthing ball points		

Table 4-5: Transformer data for IEEE 60 Hz version.

NOTE

[1] @1000m. According to IEEE C57.12, AC test voltage is altitude dependent. All values are preliminary.

[2] Based on an average of calculated values across voltages and manufacturers. All values are preliminary.
[3] Subjected to standard IEEE C57.12 tolerances. All values are preliminary.
[4] Transformer max altitude may be adjusted to match turbine location.
[5] Information values based on operation mode, see Figure 4-1.

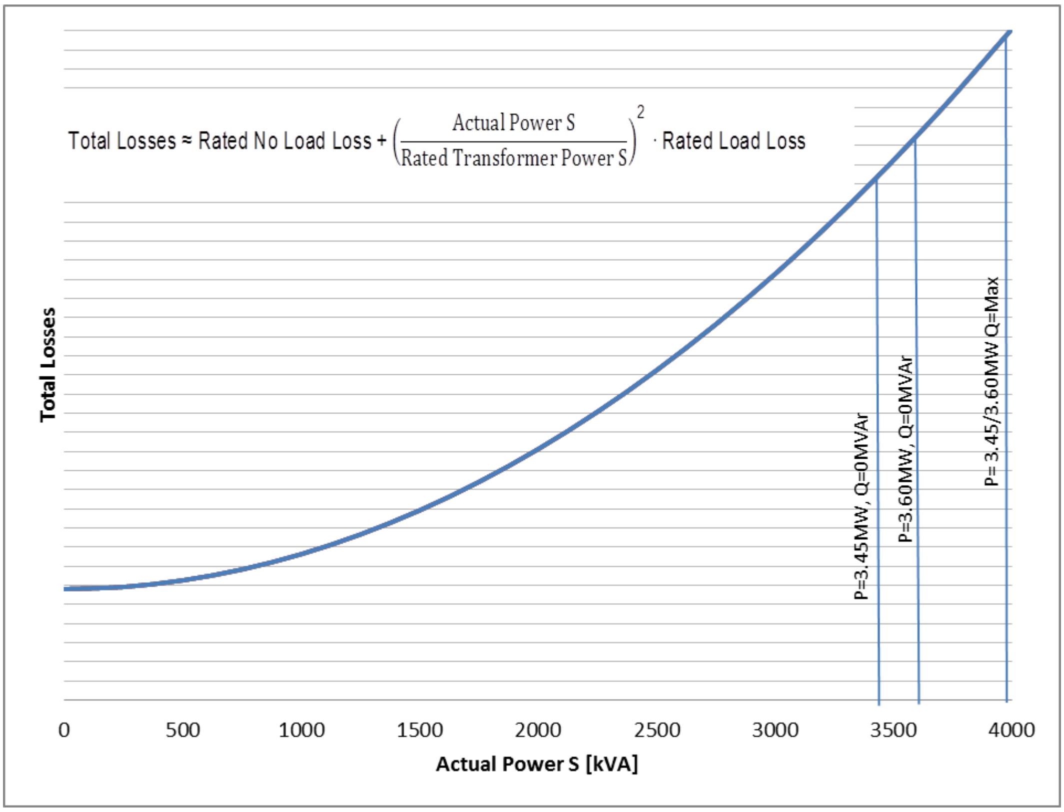

Figure 4-1: Total Losses vs. Actual Power.

4.4 HV Cables

The high-voltage cable runs from the transformer in the nacelle down the tower to the HV switchgear located at the bottom of the tower. The high-voltage cable is a four-core, rubber-insulated, halogen-free, high-voltage cable.

HV Cables	
High-Voltage Cable Insulation Compound	Improved ethylene-propylene (EP) based material-EPR or high modulus or hard grade ethylene-propylene rubber-HEPR
Conductor Cross Section	3 x 70 / 70 mm^2
Maximum Voltage	24 kV for 10.0-22.0 kV rated voltage 42 kV for 22.1-36.0 kV rated voltage

Table 4-6: HV cables data.

4.5 HV Switchgear

A gas insulated switchgear is installed in the bottom of the tower as an integrated part of the turbine. Its controls are integrated with the turbine safety system which monitors the condition of the switchgear and high voltage safety related devices in the turbine. This ensures all protection devices are fully operational whenever high voltage components in the turbine are energised. The earthing switch of the circuit breaker contains a trapped-key interlock system with its counterpart installed on the access door to the transformer room in order to avoid unauthorized access to the transformer room during live condition.

The switchgear is available in three variants with increasing features, see Table 4-7. Beside the increase in features, the switchgear can be configured depending on the number of grid cables planned to enter the individual turbine. The design of the switchgear solution is optimized such grid cables can be connected to the switchgear even before the tower is installed and still maintain its protection toward weather conditions and internal condensation due to a gas tight packing.

The switchgear is available in an IEC version and in an IEEE version. The IEEE version is however only available in the highest voltage class. The electrical parameters of the switchgear are seen in Table 4-8 for the IEC version and in Table 4-9 for the IEEE version.

HV Switchgear			
Variant	**Basic**	**Streamline**	**Standard**
IEC standards	○	⊙	⊙
IEEE standards	⊙	○	⊙
Vacuum circuit breaker panel	⊙	⊙	⊙
Overcurrent, short-circuit and earth fault protection	⊙	⊙	⊙
Disconnector / earthing switch in circuit breaker panel	⊙	⊙	⊙
Voltage Presence Indicator System for circuit breaker	⊙	⊙	⊙
Voltage Presence Indicator System for grid cables	⊙	⊙	⊙
Double grid cable connection	⊙	⊙	⊙
Triple grid cable connection	⊙	○	○
Preconfigured relay settings	⊙	⊙	⊙
Turbine safety system integration	⊙	⊙	⊙
Redundant trip coil circuits	⊙	⊙	⊙
Trip coil supervision	⊙	⊙	⊙
Pendant remote control from outside of tower	⊙	⊙	⊙
Sequential energization	⊙	⊙	⊙
Reclose blocking function	⊙	⊙	⊙

HV Switchgear			
Variant	**Basic**	**Streamline**	**Standard**
Heating elements	⦿	⦿	⦿
Trapped-key interlock system for circuit breaker panel	⦿	⦿	⦿
UPS power back-up for protection circuits	⦿	⦿	⦿
Motor operation of circuit breaker	⦿	⦿	⦿
Cable panel for grid cables (configurable)	○	⦿	⦿
Switch disconnector panels for grid cables – max three panels (configurable)	○	⦿	⦿
Earthing switch for grid cables	○	⦿	⦿
Internal arc classification	○	⦿	⦿
Supervision on MCB's	○	⦿	⦿
Motor operation of switch disconnector	○	○	⦿
SCADA operation and feedback of circuit breaker	○	○	⦿
SCADA operation and feedback of switch disconnector	○	○	⦿

Table 4-7: HV switchgear variants and features.

4.5.1 IEC 50/60Hz version

HV Switchgear	
Type description	Gas Insulated Switchgear
Applied standards	IEC 62271-103 IEC 62271-1, 62271-100, 62271-102, 62271-200, IEC 60694
Insulation medium	SF_6
Rated voltage	
U_r 24.0kV	10.0-22.0 kV
U_r 36.0kV	22.1-33.0 kV
U_r 40.5kV	33.1-36.0 kV
Rated insulation level AC // LI **Common value / across isolation distance**	
U_r 24.0kV	50 / 60 // 125 / 145 kV
U_r 36.0kV	70 / 80 // 170 / 195 kV
U_r 40.5kV	85 / 90 // 185 / 215 kV
Rated frequency	50 Hz / 60 Hz
Rated normal current	630 A
Rated Short-time withstand current	
U_r 24.0kV	20 kA
U_r 36.0kV	25 kA
U_r 40.5kV	25 kA
Rated peak withstand current **50 / 60 Hz**	
U_r 24.0kV	50 / 52 kA
U_r 36.0kV	62.5 / 65 kA

HV Switchgear	
U_r 40.5kV	62.5 / 65 kA
Rated duration of short-circuit	1 s
Internal arc classification (option)	
U_r 24.0kV	IAC A FLR 20 kA, 1 s
U_r 36.0kV	IAC A FLR 25 kA, 1 s
U_r 40.5kV	IAC A FLR 25 kA, 1 s
Connection interface	Outside cone plug-in bushings, IEC interface C1, M16.
Loss of service continuity category	LSC2
Ingress protection	
Gas tank	IP 65
Enclosure	IP 2X
LV cabinet	IP 2X
Corrosion class	C3

Table 4-8: HV switchgear data for IEC version.

4.5.2 IEEE 60Hz version

HV Switchgear	
Type description	Gas Insulated Switchgear
Applied standards	IEEE 37.20.3, IEEE C37.20.4, IEC 62271-200, ISO 12944.
Insulation medium	SF_6
Rated voltage	
U_r 38.0kV	22.1-36.0 kV
Rated insulation level AC / LI	70 / 150 kV
Rated frequency	60 Hz
Rated normal current	600 A
Rated Short-time withstand current	25 kA
Rated peak withstand current	65 kA
Rated duration of short-circuit	1 s
Internal arc classification (option)	IAC A FLR 25 kA, 1 s
Connection interface grid cables	Outside cone plug-in bushings, IEEE 386 interface type deadbreak, 600A.
Ingress protection	
Gas tank	NEMA 4X / IP 65
Enclosure	NEMA 2 / IP 2X
LV cabinet	NEMA 2 / IP 2X
Corrosion class	C3

Table 4-9: HV switchgear data for IEEE version.

4.6 AUX System

The AUX system is supplied from a separate 650/400/230 V transformer located in the nacelle inside the converter cabinet. All motors, pumps, fans and heaters are supplied from this system.

230 V consumers are generally supplied from a 400/230 V transformer located in the tower base. Internal heating and ventilation of cabinets as well as specific option 230 V consumers are supplied from the auxiliary transformer in the converter cabinet.

Power Sockets	
Single Phase (Nacelle)	230 V (16 A) (standard) 110 V (16 A) (option) 2 x 55 V (16 A) (option)
Single Phase (Tower Platforms)	230 V (10 A) (standard) 110 V (16 A) (option) 2 x 55 V (16 A) (option)
Three Phase (Nacelle and Tower Base)	3 x 400 V (16 A)

Table 4-10: AUX system data.

4.7 Wind Sensors

The turbine is equipped with two ultrasonic wind sensors. The sensors have built-in heaters to minimise interference from ice and snow. The wind sensors are redundant, and the turbine is able to operate with one sensor only.

4.8 Vestas Multi Processor (VMP) Controller

The turbine is controlled and monitored by the VMP8000 control system.

VMP8000 is a multiprocessor control system comprised of main controller, distributed control nodes, distributed IO nodes and ethernet switches and other network equipment. The main controller is placed in the tower bottom of the turbine. It runs the control algorithms of the turbine, as well as all IO communication.

The communications network is a time triggered Ethernet network (TTEthernet).

The VMP8000 control system serves the following main functions:

- Monitoring and supervision of overall operation.
- Synchronizing of the generator to the grid during connection sequence.
- Operating the wind turbine during various fault situations.
- Automatic yawing of the nacelle.
- OptiTip® - blade pitch control.
- Reactive power control and variable speed operation.
- Noise emission control.
- Monitoring of ambient conditions.
- Monitoring of the grid.
- Monitoring of the smoke detection system.

4.9 Uninterruptible Power Supply (UPS)

During grid outage, an UPS system will ensure power supply for specific components.

The UPS system is built by 3 subsystems:

1. 230V AC UPS for all power backup to nacelle and hub control systems

2. 24V DC UPS for power backup to tower base control systems and optional network communication/fiber switch to SCADA Power Plant Controller.
3. 230V AC UPS for power backup to internal lights in tower and nacelle. Internal light in the hub is fed from built-in batteries in the light armature.

UPS		
Backup Time	**Standard**	**Optional**
Control System* **(230V AC and 24V DC UPS)**	15 min	Up to 400 min**
Internal Lights **(230V AC UPS)**	30 min	60 min***
Optional network communication/fiber switch to SCADA Power Plant Controller **(24V DC UPS)**	N/A	48 hours****

Table 4-11: UPS data.

**The control system includes: the turbine controller (VMP8000), HV switchgear functions, and remote control system.*

***Requires upgrade of the 230V UPS for control system with extra batteries.*

****Requires upgrade of the 230V UPS for internal light with extra batteries.*

*****Requires upgrade of the 24V DC UPS with extra batteries.*

NOTE For alternative backup times, consult Vestas.

5 Turbine Protection Systems

5.1 Braking Concept

The main brake on the turbine is aerodynamic. Stopping the turbine is done by full feathering the three blades (individually turning each blade). Each blade has a hydraulic accumulator to supply power for turning the blade.

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

5.2 Short Circuit Protections

Breakers	Breaker for Aux. Power. T4L 250A TMA 690 V	Breaker 1 for Converter Modules Emax 2.2N 1600A 690 V	Breaker 2 for Converter Modules Emax 4.2N 3200A 690 V
Breaking Capacity Icu, Ics	70 kA rms @ max 690 V Ics = 100%	66 kA rms @ max 690 V Ics = 100%	66 kA rms @ max 690 V Ics = 100%
Making Capacity Icm	154 kA peak @ max 690 V	166 kA peak @ max 690 V	166 kA peak @ max 690 V

Table 5-1: Short circuit protection data.

5.3 Overspeed Protection

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

The safety-related partition of the VMP8000 control system monitors the rotor rpm. In case of an overspeed situation, the safety-related partition of the VMP8000 control system activates the emergency feathered position (full feathering) of the three blades independently of the non-safety related partition of VMP8000 control system.

Overspeed Protection	
Sensors Type	Inductive
Trip Level (variant dependent)	14.0-17.6 rpm / 2000 (generator rpm)

Table 5-3: Overspeed protection data.

5.4 Arc Detection

The turbine is equipped with an Arc Detection system including multiple optical arc detection sensors placed in the HV transformer compartment and the converter cabinet. The Arc Detection system is connected to the turbine safety system ensuring immediate opening of the HV switchgear if an arc is detected.

5.5 Smoke Detection

The turbine is equipped with a Smoke Detection system including multiple smoke detection sensors placed in the nacelle (above the disc brake), in the transformer compartment, in main electrical cabinets in the nacelle and above the HV switchgear in the tower base. The Smoke Detection system is connected to the turbine safety system ensuring immediate opening of the HV switchgear if smoke is detected.

5.6 Lightning Protection of Blades, Nacelle, Hub and Tower

The Lightning Protection System (LPS) helps protect the wind turbine against the physical damage caused by lightning strikes. The LPS consists of five main parts:

- Lightning receptors. All lightning receptor surfaces on the blades are unpainted, excluding the Solid Metal Tips (SMT).
- Down conducting system (a system to conduct the lightning current down through the wind turbine to help avoid or minimise damage to the LPS itself or other parts of the wind turbine).
- Protection against overvoltage and overcurrent.
- Shielding against magnetic and electrical fields.
- Earthing system.

Lightning Protection Design Parameters			Protection Level I
Current Peak Value	i_{max}	[kA]	200
Impulse Charge	$Q_{impulse}$	[C]	100
Long Duration Charge	Q_{long}	[C]	200
Total Charge	Q_{total}	[C]	300
Specific Energy	W/R	[MJ/Ω]	10
Average Steepness	di/dt	[kA/μs]	200

Table 5-4: Lightning protection design parameters.

NOTE The Lightning Protection System is designed according to IEC standards (see section 8 Design Codes, p. 29).

5.7 EMC

The turbine and related equipment fulfils the EU Electromagnetic Compatibility (EMC) legislation:

- DIRECTIVE 2014/30/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 26 February 2014 on the harmonisation of the laws of the Member States relating to electromagnetic compatibility.

5.8 Earthing

The Vestas Earthing System consists of a number of individual earthing electrodes interconnected as one joint earthing system.

The Vestas Earthing System includes the TN-system and the Lightning Protection System for each wind turbine. It works as an earthing system for the medium voltage distribution system within the wind farm.

The Vestas Earthing System is adapted for the different types of turbine foundations. A separate set of documents describe the earthing system in detail, depending on the type of foundation.

In terms of lightning protection of the wind turbine, Vestas has no separate requirements for a certain minimum resistance to remote earth (measured in ohms) for this system. The earthing for the lightning protection system is based on the design and construction of the Vestas Earthing System.

A primary part of the Vestas Earthing System is the main earth bonding bar placed where all cables enter the wind turbine. All earthing electrodes are connected to this main earth bonding bar. Additionally, equipotential connections are made to all cables entering or leaving the wind turbine.

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.

5.9 Corrosion Protection

Classification of corrosion protection is according to ISO 12944-2.

Corrosion Protection	External Areas	Internal Areas
Nacelle	C5-M	C3
Hub	C5-M	C3
Tower	C5-I	C3

Table 5-5: Corrosion protection data for nacelle, hub, and tower.

6 Safety

The safety specifications in this 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, and (c) conducting all appropriate safety training and education.

6.1 Access

Access to the turbine from the outside is through a door located at the entrance platform approximately 3 meter above ground level. The door is equipped with a lock. Access to the top platform in the tower is by a ladder or service lift.

Access to the nacelle from the top platform is by ladder. Access to the transformer room in the nacelle is controlled with a lock. Unauthorised access to electrical switchboards and power panels in the turbine is prohibited according to IEC 60204-1 2006.

6.2 Escape

In addition to the normal access routes, alternative escape routes from the nacelle are through the crane hatch, from the spinner by opening the nose cone, or from the roof of the nacelle. Rescue equipment is placed in the nacelle.

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

Escape from the service lift is by ladder.

An emergency response plan, placed in the turbine, describes evacuation and escape routes.

6.3 Rooms/Working Areas

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

6.4 Floors, Platforms, Standing, and Working Places

All floors have anti-slip surfaces.

There is one floor per tower section. Rest platforms are provided at intervals of 9 metres along the tower ladder between platforms.

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

6.5 Service Lift

The turbine is delivered with a service lift installed as an option.

6.6 Climbing Facilities

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

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

Over the crane hatch there is an anchor point for the emergency descent equipment.

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

6.7 Moving Parts, Guards, and Blocking Devices

All moving parts in the nacelle are shielded.

The turbine is equipped with a rotor lock to block the rotor and drive train.

Blocking the pitch of the cylinder can be done with mechanical tools in the hub.

6.8 Lights

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

There is emergency light in case of the loss of electrical power.

6.9 Emergency Stop

There are emergency stop buttons in the nacelle, hub and bottom of the tower.

6.10 Power Disconnection

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

6.11 Fire Protection/First Aid

A handheld 5-6 kg CO_2 fire extinguisher, first aid kit and fire blanket are required to be located in the nacelle during service and maintenance.

- A handheld 5-6 kg CO_2 fire extinguisher is required only during service and maintenance activities, unless a permanently mounted fire extinguisher located in the nacelle is mandatorily required by authorities.
- First aid kits are required only during service and maintenance activities.
- Fire blankets are required only during non-electrical hot work activities.

6.12 Warning Signs

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

6.13 Manuals and Warnings

The Vestas Corporate 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.

7 Environment

7.1 Chemicals

Chemicals used in the turbine are evaluated according to the Vestas Wind Systems A/S Environmental System certified according to ISO 14001:2015. The following chemicals are used in the turbine:

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

8 Design Codes

8.1 Design Codes – Structural Design

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

Design Codes	
Nacelle and Hub	IEC 61400-1 Edition 3 EN 50308
Tower	IEC 61400-1 Edition 3 Eurocode 3
Blades	DNV-OS-J102 IEC 1024-1

Design Codes	
	IEC 60721-2-4 IEC 61400 (Part 1, 12 and 23) IEC WT 01 IEC DEFU R25 ISO 2813 DS/EN ISO 12944-2
Gearbox	ISO 81400-4
Generator	IEC 60034
Transformer	IEC 60076-11, IEC 60076-16, CENELEC HD637 S1
Lightning Protection	IEC 62305-1: 2006 IEC 62305-3: 2006 IEC 62305-4: 2006 IEC 61400-24:2010
Rotating Electrical Machines	IEC 34
Safety of Machinery, Safety-related Parts of Control Systems	IEC 13849-1
Safety of Machinery – Electrical Equipment of Machines	IEC 60204-1

Table 8-1: Design codes.

9 Colours

9.1 Nacelle Colour

Colour of Vestas Nacelles	
Standard Nacelle Colour	RAL 7035 (light grey)
Standard Logo	Vestas

Table 9-1: Colour, nacelle.

9.2 Tower Colour

Colour of Vestas Tower Section		
	External:	**Internal:**
Standard Tower Colour	RAL 7035 (light grey)	RAL 9001 (cream white)

Table 9-2: Colour, tower.

9.3 Blade Colour

Blade Colour	
Standard Blade Colour	RAL 7035 (light grey). All lightning receptor surfaces on the blades are unpainted, excluding the Solid Metal Tips (SMT).
Tip-End Colour Variants	RAL 2009 (traffic orange), RAL 3020 (traffic red)
Gloss	< 30% DS/EN ISO 2813

Table 9-3: Colour, blades.

10 Operational Envelope and Performance Guidelines

Actual climate and site conditions have many variables and should 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.

10.1 Climate and Site Conditions

Values refer to hub height:

Extreme Design Parameters	
Wind Climate	**All**
Ambient Temperature Interval (Standard Temperature Turbine)	-40° to +50°C

Table 10-1: Extreme design parameters.

10.2 Operational Envelope – Temperature and Altitude

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

Operational Envelope – Temperature	
Ambient Temperature Interval (Standard Turbine)	-20° to +45°C
Ambient Temperature Interval (Low Temperature Turbine)	-30° to +45°C

Table 10-2: Operational envelope – temperature.

NOTE The wind turbine will stop producing power at ambient temperatures above 45°C.

For the low temperature options of the wind turbine, consult Vestas.

The turbine is designed for use at altitudes up to 1000 m above sea level as standard and optional up to 2000 m above sea level.

10.3 Operational Envelope – Temperature and Altitude Derating in 3.45 MW Mode 0

Values below refer to hub height and are determined by the sensors and control system of the turbine. At ambient temperatures above an altitude-specific threshold (+30°C for ≤1250 m.a.s.l.), the turbine will maintain derated production in 3.45 MW Mode 0, within the component capacity as seen in Figure 10-1.

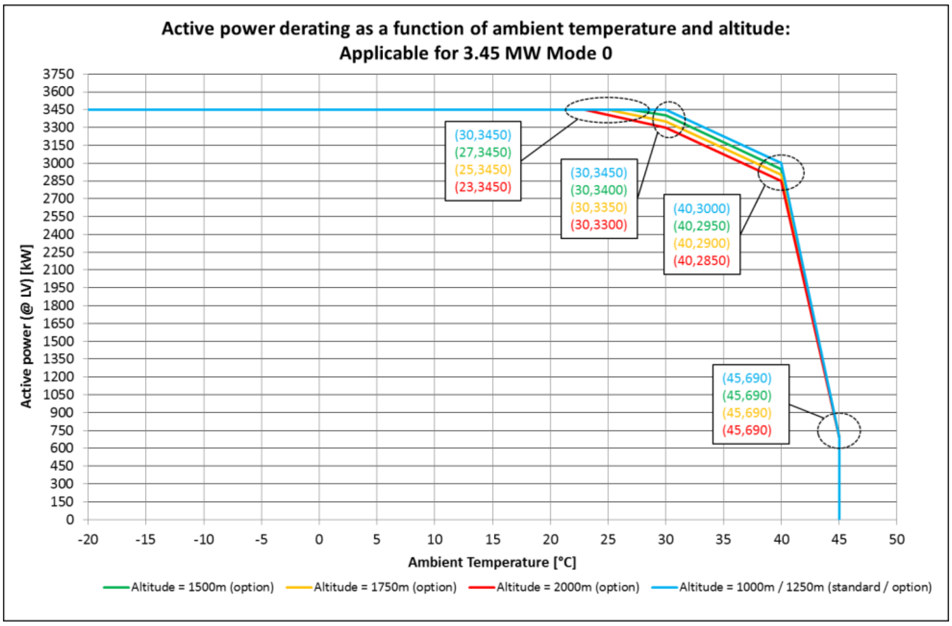

Figure 10-1: Temperature and altitude derated operation for 3.45 MW Mode 0.

10.4 Operational Envelope – Temperature and Altitude Derating in 3.6 MW Power Optimized Mode (PO1)

Derating chart for 3.6 MW Power Optimized Mode (PO1) is shown in Figure 10-2.

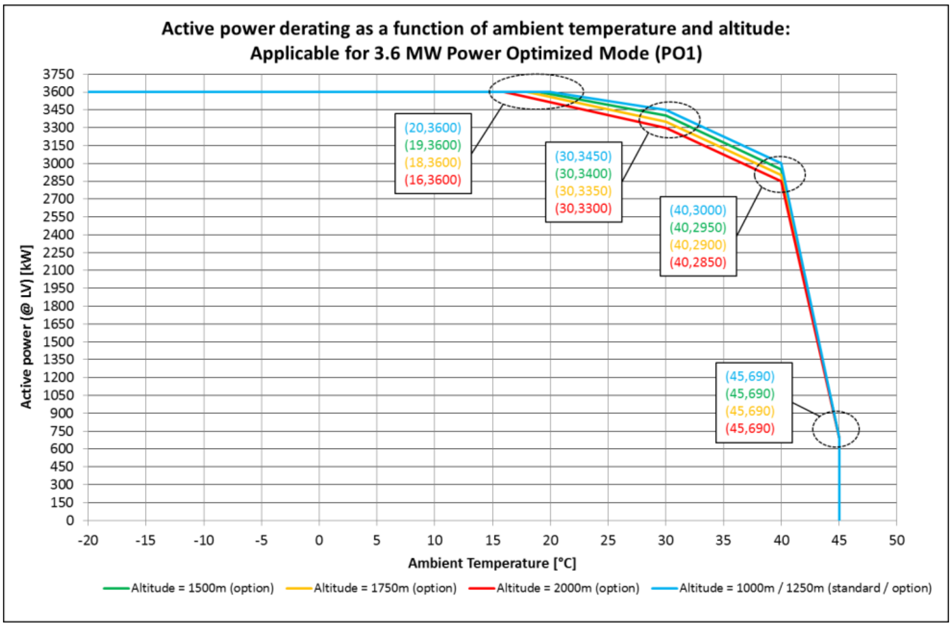

Figure 10-2: Temperature and altitude derated operation for 3.6 MW Power Optimized Mode (PO1).

10.5 Operational Envelope – Temperature and Altitude Derating in 3.3 MW Load Optimized Mode (LO1)

Derating chart for 3.3 MW Load Optimized Mode (LO1) is shown in Figure 10-3.

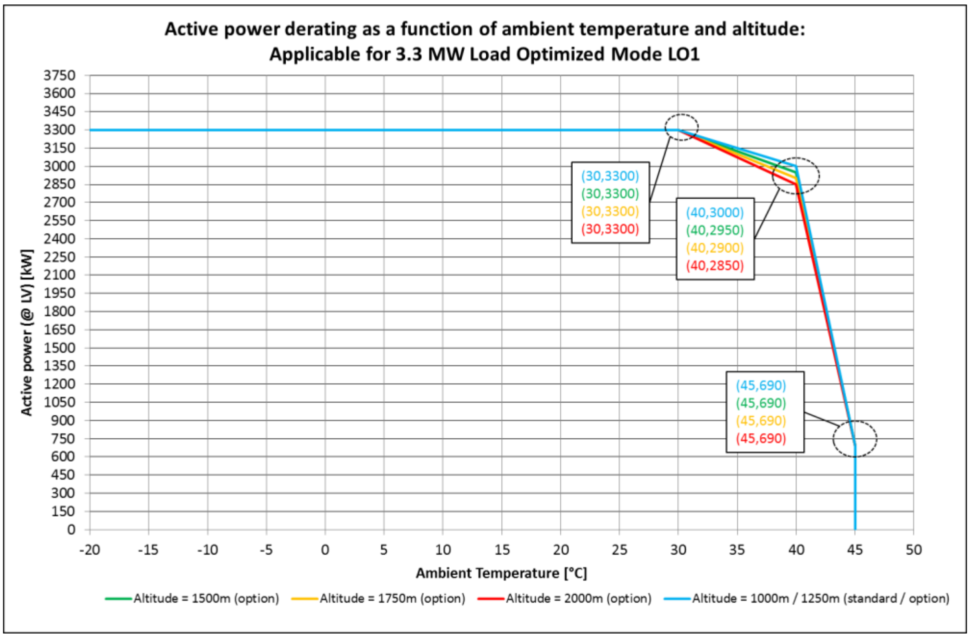

Figure 10-3: Temperature and altitude derated operation for 3.3 MW Load Optimized Mode (LO1).

10.6 Operational Envelope – Temperature and Altitude Derating in 3.0 MW Load Optimized Mode (LO2)

Derating chart for 3.0 MW Load Optimized Mode (LO2) is shown in Figure 10-4.

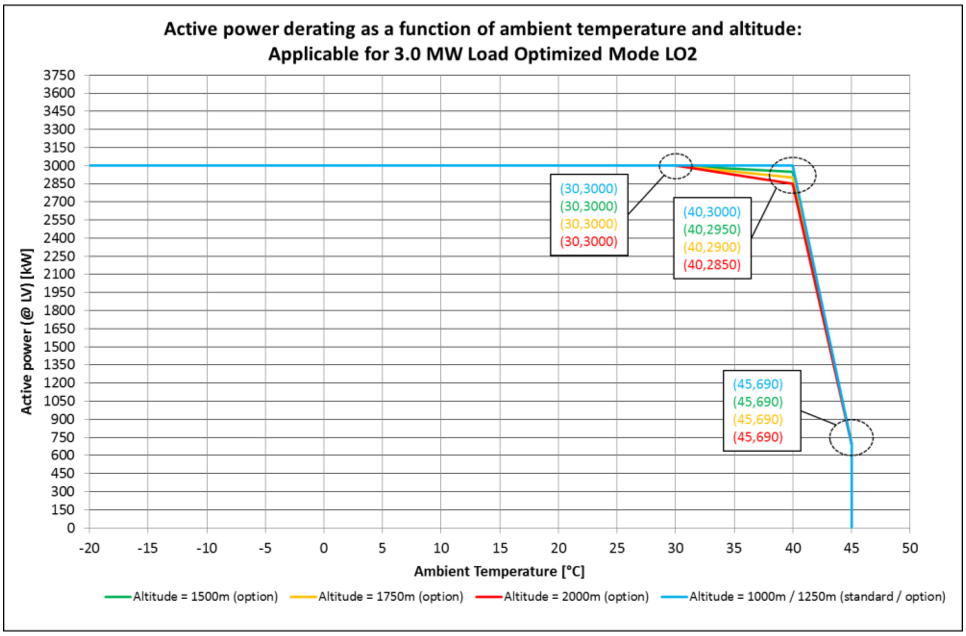

Figure 10-4: Temperature and altitude derated operation for 3.0 MW Load Optimized Mode (LO2).

10.7 Operational Envelope – Grid Connection

Operational Envelope – Grid Connection		
Nominal Phase Voltage	[U_{NP}]	650 V
Nominal Frequency	[f_N]	50/60 Hz
Maximum Frequency Gradient	±4 Hz/sec.	
Maximum Negative Sequence Voltage	3% (connection) / 2% (operation)	
Minimum Required Short Circuit Ratio (SCR) at Turbine HV Connection	5.0 (contact Vestas for project-specific evaluation for SCRs <5.0)	
Maximum Short Circuit Current Contribution	1.05 p.u. (continuous) 1.45 p.u. (peak)	

Table 10-3: Operational envelope – grid connection.

The generator and the converter will be disconnected if*:

Protection Settings	
Voltage Above 110% of Nominal for 3600 Seconds**	715 V
Voltage Above 121% of Nominal for 2 Seconds	787 V
Voltage Above 136% of Nominal for 0.150 Seconds	884 V
Voltage Below 90% of Nominal for 180 Seconds (FRT)**	585 V
Voltage Below 85% of Nominal for 12 Seconds (FRT)**	553 V
Voltage Below 80% of Nominal for 4 Seconds (FRT)	520 V
Frequency is Above 106% of Nominal for 0.2 Seconds	53/63.6 Hz
Frequency is Below 94% of Nominal for 0.2 Seconds	47/56.4 Hz

Table 10-4: 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.

** The turbine may be configured for continuous operation @ +/- 13 % voltage. Reactive power capability is limited for these widened settings (See section 10.8).

10.8 Operational Envelope – Reactive Power Capability in 3.45 MW Mode 0

The 3.45 MW turbine has a reactive power capability in Mode 0 on the low voltage side of the HV transformer as illustrated in Figure 10-5:

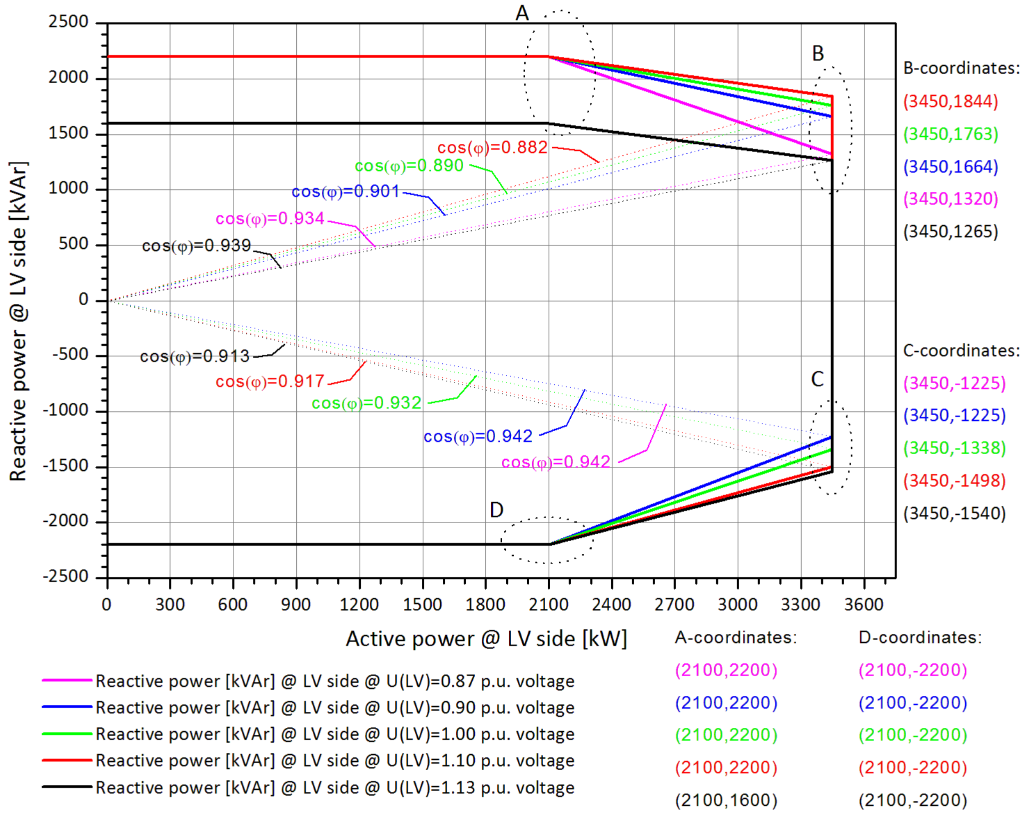

Figure 10-5: Reactive power capability for 3.45 MW Mode 0.

When operating at 3.45 MW nominal power at LV side of the HV transformer, the reactive power capability on the high voltage side of the HV transformer is approximately:

- cosφ(HV) = 0.95 capacitive @ U(HV) = 0.87 p.u. voltage
- cosφ(HV) = 0.94/0.94 capacitive/inductive @ U(HV) = 0.88 p.u. voltage
- cosφ(HV) = 0.93/0.91 capacitive/inductive @ U(HV) = 0.90 p.u. voltage
- cosφ(HV) = 0.92/0.90 capacitive/inductive @ U(HV) = 1.00 p.u. voltage
- cosφ(HV) = 0.95/0.89 capacitive/inductive @ U(HV) = 1.10 p.u. voltage
- cosφ(HV) = 0.98/0.89 capacitive/inductive @ U(HV) = 1.13 p.u. voltage

Reactive power is produced by the full-scale converter. Traditional capacitors are, therefore, not used in the turbine.

The turbine is able to maintain the reactive power capability at low wind with no active power production.

NOTE 3.45 MW Mode 0 derates above +30°C ambient temperature for ≤1250 m.a.s.l. according to Figure 10-1.

10.9 Operational Envelope – Reactive Power Capability in 3.45 MW Reactive Power Optimized Mode (QO1)

An optional, extended reactive power capability is available with 3.45 MW Reactive Power Optimized Mode (QO1) when ambient temperature is below +20°C for ≤1250 m.a.s.l. The reactive power capability is as seen in Figure 10-6:

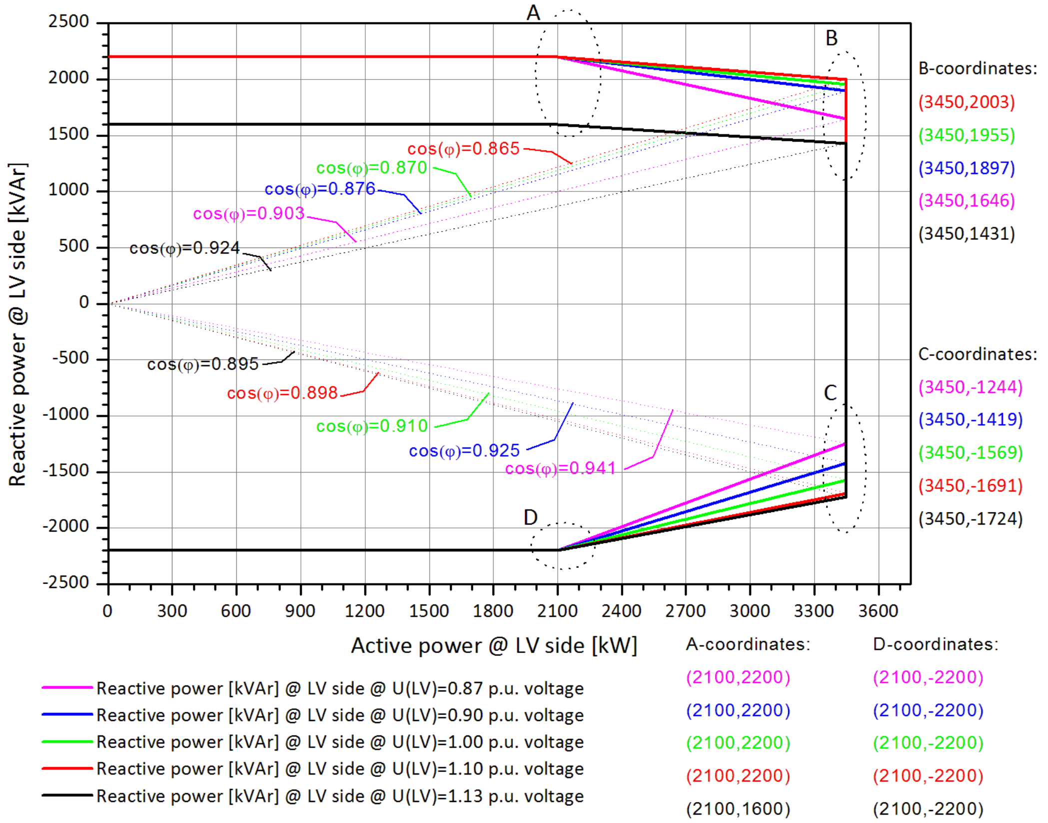

Figure 10-6: Reactive power capability for 3.45 MW Reactive Power Optimized Mode (QO1).

When operating at 3.45 MW in Reactive Power Optimized Mode (QO1) at LV side of the HV transformer, the reactive power capability on the high voltage side of the HV transformer is approximately:

- cosφ(HV) = 0.92 capacitive @ U(HV) = 0.87 p.u. voltage
- cosφ(HV) = 0.92/0.91 capacitive/inductive @ U(HV) = 0.89 p.u. voltage
- cosφ(HV) = 0.91/0.90 capacitive/inductive @ U(HV) = 0.90 p.u. voltage
- cosφ(HV) = 0.90/0.88 capacitive/inductive @ U(HV) = 1.00 p.u. voltage
- cosφ(HV) = 0.94/0.87 capacitive/inductive @ U(HV) = 1.10 p.u. voltage
- cosφ(HV) = 0.97/0.87 capacitive/inductive @ U(HV) = 1.13 p.u. voltage

The turbine is able to maintain the reactive power capability at low wind with no active power production.

NOTE

3.45 MW Reactive Power Optimized Mode (QO1) derates reactive power linearly above +20°C ambient temperature for ≤1250 m.a.s.l. to converge with the reactive power capability of 3.45 MW Mode 0 in Figure 10-5 at +30°C.

10.10 Operational Envelope – Reactive Power Capability in 3.6 MW Power Optimized Mode (PO1)

The reactive power capability for the 3.6 MW Power Optimized Mode (PO1) is as illustrated in Figure 10-7:

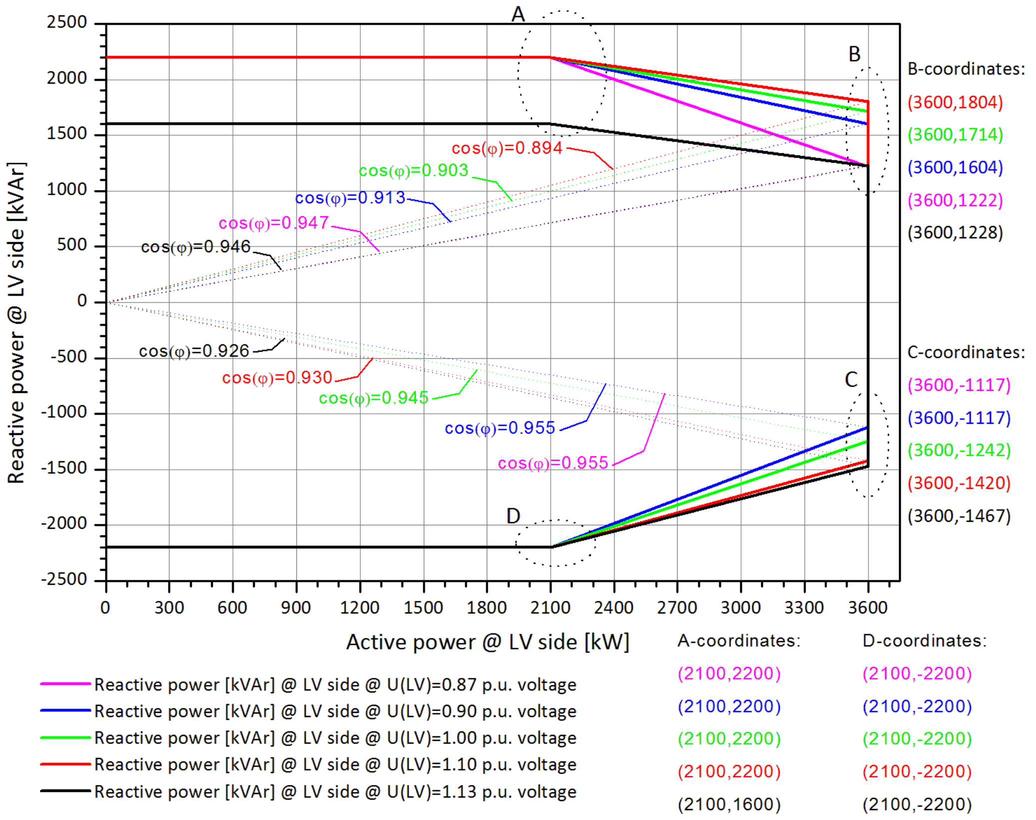

Figure 10-7: Reactive power capability for 3.6 MW Power Optimized Mode (PO1).

When operating at 3.6 MW in Power Optimized Mode (PO1) at LV side of the HV transformer, the reactive power capability on the high voltage side of the HV transformer is approximately:

- cosφ(HV) = 0.96 capacitive @ U(HV) = 0.87 p.u. voltage
- cosφ(HV) = 0.95/0.94 capacitive/inductive @ U(HV) = 0.88 p.u. voltage
- cosφ(HV) = 0.95/0.92 capacitive/inductive @ U(HV) = 0.90 p.u. voltage
- cosφ(HV) = 0.93/0.92 capacitive/inductive @ U(HV) = 1.00 p.u. voltage
- cosφ(HV) = 0.96/0.91 capacitive/inductive @ U(HV) = 1.10 p.u. voltage

  cosφ(HV) = 0.98/0.90 capacitive/inductive @ U(HV) = 1.13 p.u. voltage

The turbine is able to maintain the reactive power capability at low wind with no active power production.

NOTE

3.6 MW Power Optimized Mode (PO1) derates above +20°C ambient temperature for ≤1250 m.a.s.l. according to Figure 10-2.

3.6 MW Power Optimized Mode (PO1) is mutually exclusive with 3.45 MW Reactive Power Optimized Mode (QO1) (since Q is traded for P).

10.11 Operational Envelope – Reactive Power Capability in 3.3 MW Load Optimized Mode (LO1)

The reactive power capability for the 3.3 MW Load Optimized Mode (LO1) is as illustrated in Figure 10-8:

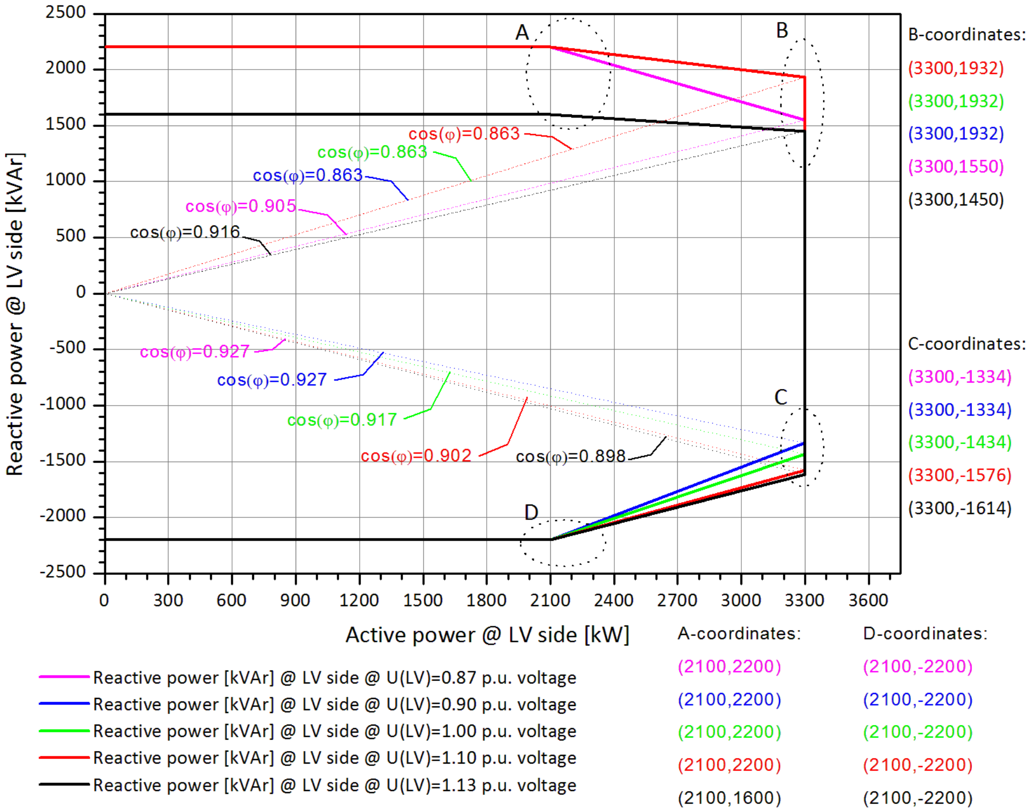

Figure 10-8: Reactive power capability for 3.3 MW Load Optimized Mode (LO1).

When operating at 3.3 MW in Load Optimized Mode (LO1) at LV side of the HV transformer, the reactive power capability on the high voltage side of the HV transformer is approximately:

- cosφ(HV) = 0.91 capacitive @ U(HV) = 0.87 p.u. voltage
- cosφ(HV) = 0.91/0.91 capacitive/inductive @ U(HV) = 0.89 p.u. voltage
- cosφ(HV) = 0.90/0.89 capacitive/inductive @ U(HV) = 0.90 p.u. voltage
- cosφ(HV) = 0.90/0.88 capacitive/inductive @ U(HV) = 1.00 p.u. voltage
- cosφ(HV) = 0.91/0.89 capacitive/inductive @ U(HV) = 1.10 p.u. voltage
- cosφ(HV) = 0.95/0.89 capacitive/inductive @ U(HV) = 1.13 p.u. voltage

The turbine is able to maintain the reactive power capability at low wind with no active power production.

NOTE 3.3 MW Load Optimized Mode (LO1) derates above +30°C ambient temperature for ≤1250 m.a.s.l. according to Figure 10-3.

10.12 Operational Envelope – Reactive Power Capability in 3.0 MW Load Optimized Mode (LO2)

The reactive power capability for the 3.0 MW Load Optimized Mode (LO2) is as illustrated in Figure 10-9:

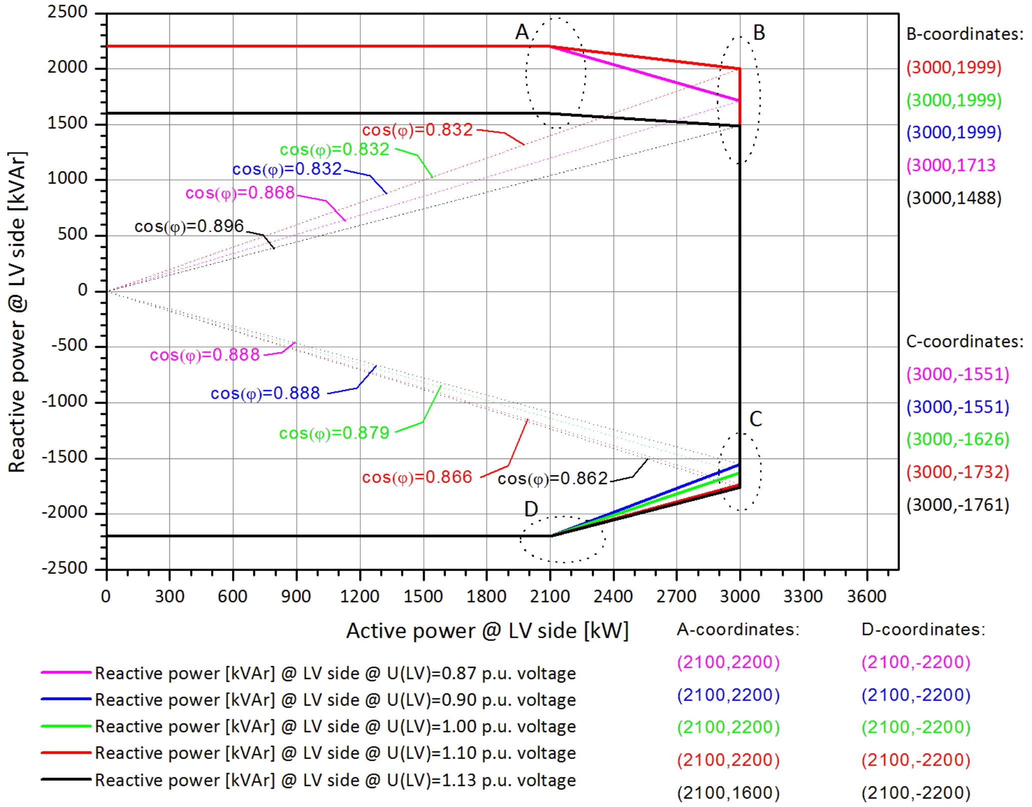

Figure 10-9: Reactive power capability for 3.0 MW Load Optimized Mode (LO2).

When operating at 3.0 MW in Load Optimized Mode (LO2) at LV side of the HV transformer, the reactive power capability on the high voltage side of the HV transformer is approximately:

- cosφ(HV) = 0.88 capacitive @ U(HV) = 0.87 p.u. voltage
- cosφ(HV) = 0.88/0.87 capacitive/inductive @ U(HV) = 0.89 p.u. voltage
- cosφ(HV) = 0.87/0.85 capacitive/inductive @ U(HV) = 0.90 p.u. voltage
- cosφ(HV) = 0.87/0.85 capacitive/inductive @ U(HV) = 1.00 p.u. voltage
- cosφ(HV) = 0.88/0.86 capacitive/inductive @ U(HV) = 1.10 p.u. voltage
- cosφ(HV) = 0.92/0.86 capacitive/inductive @ U(HV) = 1.13 p.u. voltage

The turbine is able to maintain the reactive power capability at low wind with no active power production.

NOTE 3.0 MW Load Optimized Mode (LO2) derates above +30°C ambient temperature for ≤1250 m.a.s.l. according to Figure 10-4.

10.13 Performance – Fault Ride Through

The turbine is equipped with a full-scale converter to gain better control of the wind turbine during grid faults. The turbine control system continues to run during grid faults.

The turbine is designed to stay connected during grid disturbances within the voltage tolerance curve as illustrated:

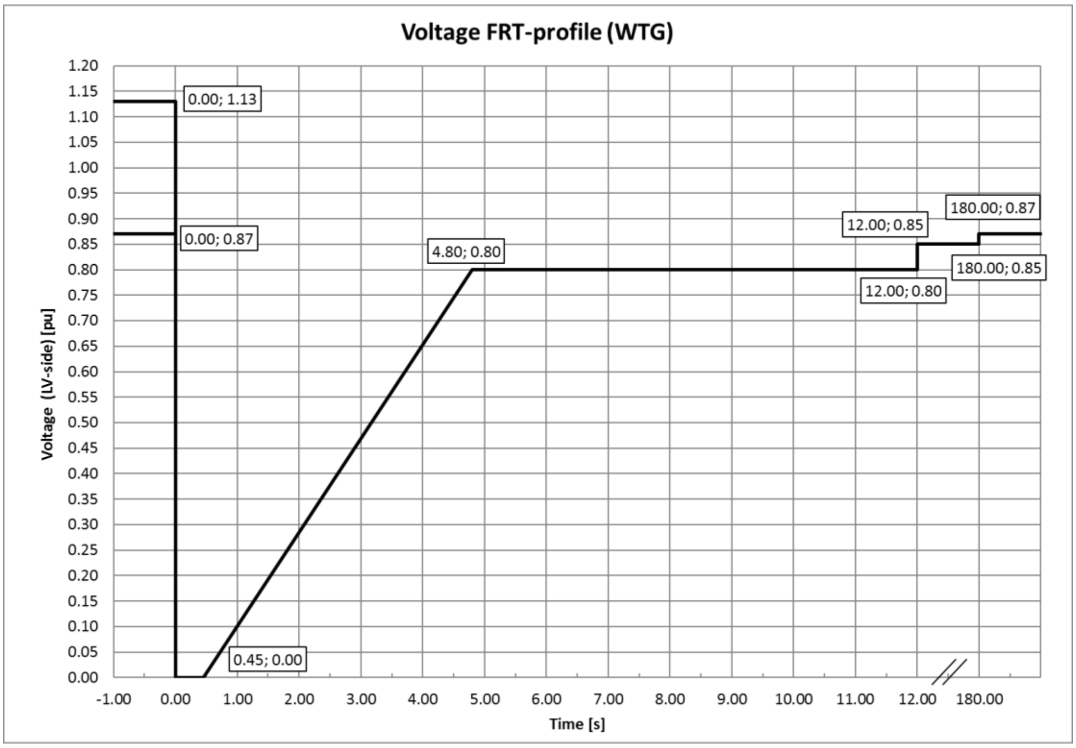

Figure 10-10: Low voltage tolerance curve for symmetrical and asymmetrical faults, where U represents voltage as measured on the grid.

For grid disturbances outside the tolerance curve in Figure 10-10, the turbine will be disconnected from the grid.

Power Recovery Time	
Power Recovery to 90% of Pre-Fault Level	Maximum 0.1 seconds

Table 10-5: Power recovery time

10.14 Performance – Reactive Current Contribution

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

10.14.1 Symmetrical Reactive Current Contribution

During symmetrical voltage dips, the wind farm will inject reactive current to support the grid voltage. The reactive current injected is a function of the measured grid voltage.

The default value gives a reactive current part of 1 p.u. of the rated active current at the high voltage side of the HV transformer. Figure 10-11, indicates the reactive current contribution as a function of the voltage. The reactive current contribution is independent from the actual wind conditions and pre-fault power level. As seen in Figure 10-11, the default current injection slope is 2% reactive current increase per 1% voltage decrease. The slope can be parameterized between 0 and 10 to adapt to site specific requirements.

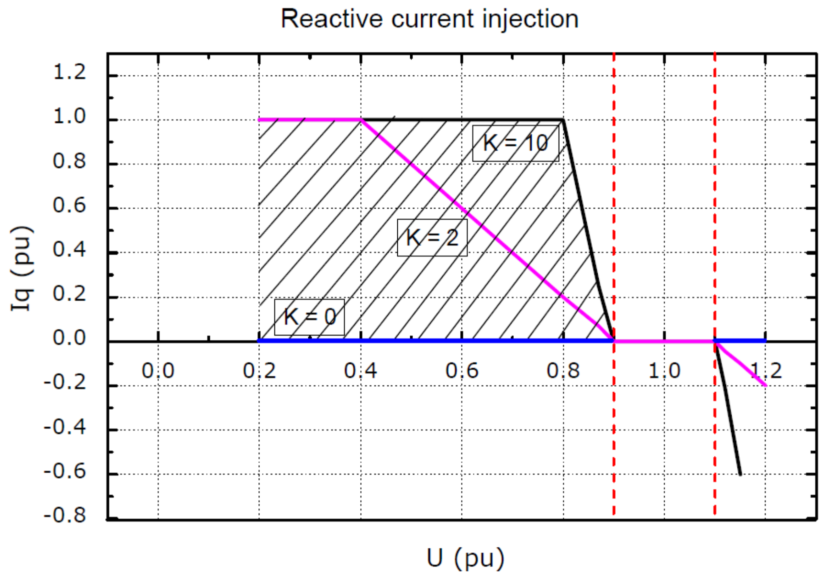

Figure 10-11: Reactive current injection.

10.14.2 Asymmetrical Reactive Current Contribution

The injected current is based on the measured positive sequence voltage and the used K-factor. During asymmetrical voltage dips, the reactive current injection is limited to approximate 0.4 p.u. to limit the potential voltage increase on the healthy phases.

10.15 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. For example, the turbine is designed to handle 10 voltage dips of duration of 200 ms, down to 20% voltage, within 30 minutes.

10.16 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 p.u./sec for max. power level change of 0.3 p.u. 0.3 p.u./sec for max. power level change of 0.1 p.u.
Reactive Power	20 p.u./sec

Table 10-6: Active/reactive power ramp rates (values are preliminary).

To support grid stability the turbine is capable to stay connected to the grid at active power references down to 10 % of nominal power for the turbine. For active power references below 10 % the turbine may disconnect from the grid.

10.17 Performance – Voltage Control

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

10.18 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.

10.19 Distortion – Immunity

The turbine is able to connect with a pre-connection (background) voltage distortion level at the grid interface of 8% and operate with a post-connection voltage distortion level of 8%.

10.20 Main Contributors to Own Consumption

The consumption of electrical power by the wind turbine is defined as the power used by the wind turbine when it is not providing energy to the grid. This is defined in the control system as Production Generator 0 (zero).

The components in Table 10-7 have the largest influence on the own consumption of the wind turbine (the average own consumption depends on the actual conditions, the climate, the wind turbine output, the cut-off hours, etc.).

The VMP8000 control system has a hibernate mode that reduces own consumption when possible. Similarly, cooling pumps may be turned off when the turbine idles.

Main contributors to Own Consumption	
Hydraulic Motor	2 x 15 kW (master/slave)
Yaw Motors	Maximum 18 kW in total
Water Heating	10 kW
Water Pumps	2.2 (3.0 kW for 60 Hz) + 4.0 kW
Oil Heating	7.9 kW
Oil Pump for Gearbox Lubrication	10 kW
Controller Including Heating Elements for the Hydraulics and all Controllers	Approximately 3 kW
HV Transformer No-load Loss	See section 4.3 HV Transformer, p. 14

Table 10-7: Main contributors to own consumption data (values are preliminary).

11 Drawings

11.1 Structural Design – Illustration of Outer Dimensions

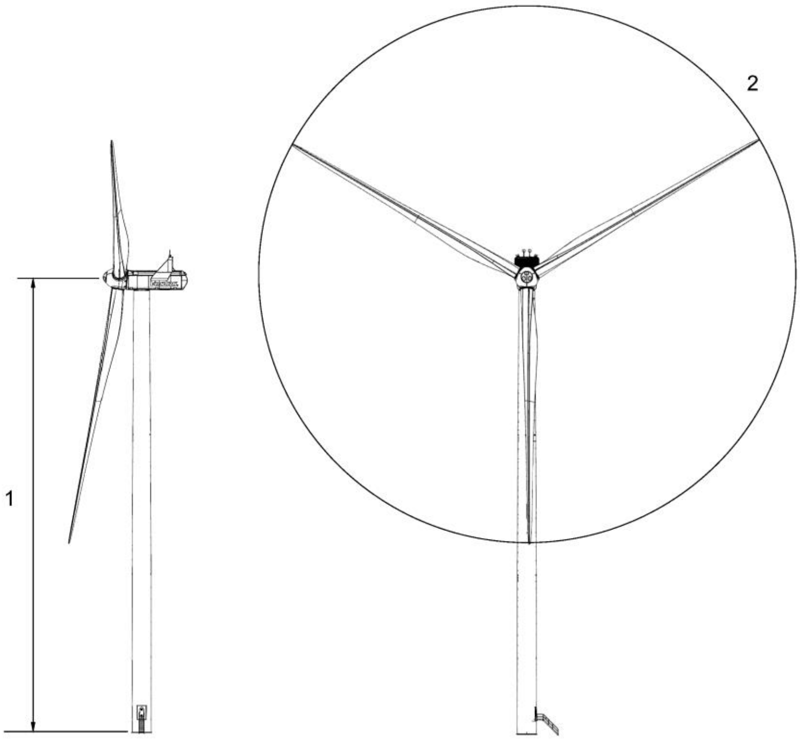

Figure 11-1: Illustration of outer dimensions – structure.

1 Hub heights: See Performance Specification

2 Rotor diameter: 105-136 m

11.2 Structural Design – Side View Drawing

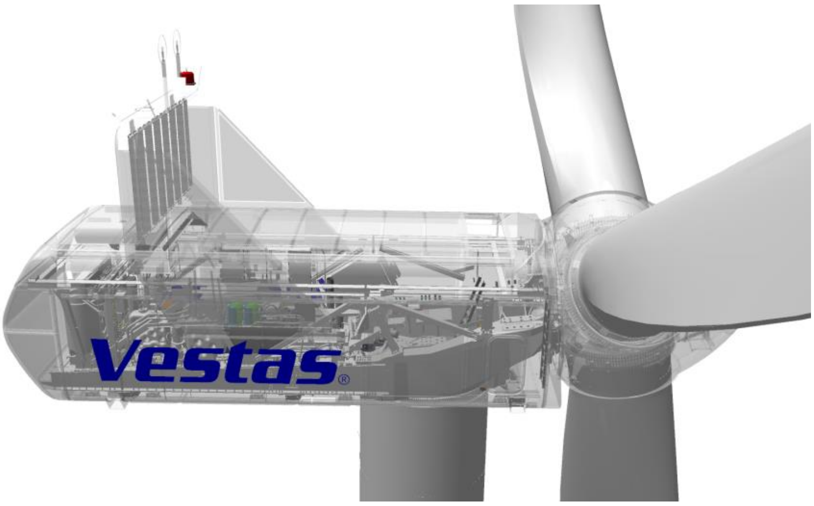

Figure 11-2: Side-view drawing.

12 General Reservations, Notes and Disclaimers

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- The general descriptions in this document apply to the current version of the 3MW Platform wind turbines. Updated versions of the 3MW Platform wind turbines, which may be manufactured in the future, may differ from this general description. In the event that Vestas supplies an updated version of a specific 3MW Platform wind turbine, Vestas will provide an updated general description applicable to the updated version.
- Vestas recommends that the grid be as close to nominal as possible with limited variation in frequency and voltage.
- A certain time allowance for turbine warm-up must be expected following grid dropout and/or periods of very low ambient temperature.
- All listed start/stop parameters (e. g. wind speeds and temperatures) are equipped with hysteresis control. This can, in certain borderline situations, result in turbine stops even though the ambient conditions are within the listed operation parameters.
- The earthing system must comply with the minimum requirements from Vestas, and be in accordance with local and national requirements and codes of standards.
- This document, General Description, is not an offer for sale, 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.