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## Appendix B

### *Turbine Specifications*



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Class I  
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# General Specification

## V90 – 1.8 MW VCUS



**Vestas**<sup>®</sup>  
No. 1 in Modern Energy

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**See section 11 ‘General Reservations, Notes and Disclaimers’, p. 34 for general reservations, notes, and disclaimers applicable to these general specifications.**

## 1 General Description

The Vestas V90-1.8 MW wind turbine is a pitch regulated upwind turbine with active yaw and a three-blade rotor. The Vestas V90-1.8 MW turbine has a rotor diameter of 90 m with a generator rated at 1.8 MW. The turbine utilizes a microprocessor pitch control system called OptiTip<sup>®</sup> and the Variable Speed concepts (VCUS: Vestas Converter Unity System). With these features the wind turbine is able to operate the rotor at variable speed (RPM), helping to maintain the output at or near rated power.

## 2 Mechanical Design

### 2.1 Rotor

The V90-1.8 MW is equipped with a 90 meter rotor consisting of three blades and the hub. Based on the prevailing wind conditions, the blades are continuously positioned to help optimise the pitch angle.

Rotor	
Diameter	90 m
Swept Area	6362 m <sup>2</sup>
Rotational Speed Static, Rotor	14.5 rpm
Speed, Dynamic Operation Range	9.0 – 14.5 rpm
Rotational Direction	Clockwise (front view)
Orientation	Upwind
Tilt	6°
Blade Coning	2°
Number of Blades	3
Aerodynamic Brakes	Full feathering

Table 2-1: Rotor data

## 2.2 Blades

The 44 m Prepreg (PP) blades are made of carbon and glass fibre and consist of two airfoil shells bonded to a supporting beam.

<b>PP Blades</b>	
<b>Type Description</b>	Airfoil shells bonded to supporting beam
<b>Blade Length</b>	44 m
<b>Material</b>	Fibreglass reinforced epoxy and carbon fibres
<b>Blade Connection</b>	Steel roots inserted
<b>Air Foils</b>	RISØ P + FFA –WA
<b>Chord:</b>	
<b>Blade root</b>	3.512 m
<b>Blade tip</b>	0.391 m
<b>Twist (blade root/blade tip)</b>	17.5°
<b>Weight</b>	6,700 kg

Table 2-2: PP blades data

## 2.3 Blade Bearing

The blade bearings are double row 4-point contact ball bearings.

<b>Blade Bearing</b>	
<b>Type</b>	2 row 4-point contact ball bearing
<b>Lubrication</b>	Grease lubrication, manually re-greased

Table 2-3: Blade bearing data

## 2.4 Pitch System

The energy input from the wind to the turbine is adjusted by pitching the blades according to the control strategy. The pitch system also works as the primary brake system by pitching the blades out of the wind. This causes the rotor to idle.

Double row 4-point contact ball bearings are used to connect the blades to the hub. The pitch system relies on hydraulics and uses a cylinder to pitch each blade. Hydraulic power is supplied to the cylinder from the hydraulic power unit in the nacelle through the main gearbox and the main shaft via a rotating transfer.

Hydraulic accumulators inside the rotor hub ensure sufficient power to stop the turbine in case of grid failure.

Pitch System	
Type	Hydraulic
Cylinder	Ø125/80 – 760
Number	1 pcs./ blade
Range	-5° to 90°

Table 2-4: Pitch system data

Hydraulic System	
Pump capacity:	44 l/min
Working pressure:	180 - 200 bar
Oil quantity:	160 l
Motor:	18.5 kW

Table 2-5: Hydraulic system data

## 2.5 Hub

The hub supports the 3 blades and transfers the reaction forces to the main bearing. The hub structure also supports blade bearings and pitch cylinder.

Hub	
Type	Cast ball shell hub
Material	Cast iron EN GJS 400-18U-LT / EN1560
Weight	8,400 kg.

Table 2-6: Hub Data

## 2.6 Main Shaft

Type:	Forged, trumpet shaft
Material:	42 CrMo4 QT / EN 10083

## 2.7 Bearing Housing

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

## 2.8 Main Bearings

Type:	Spherical roller bearings
Lubrication	Grease lubrication, manually re-greased

## 2.9 Machine Foundation

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

## 2.10 Gearbox

The main gearbox transmits torque and revolutions from the rotor to the generator.

The main gearbox consists of a planetary stage combined with a two-stage parallel gearbox, torque arms and vibration dampers.

Torque is transmitted from the high-speed shaft to the generator via a flexible composite coupling, located behind the disc brake. The disc brake is mounted directly on the high-speed shaft.

Gearbox	
Type:	1 planetary stage / 2 helical stages
Ratio:	60 Hz: 1:92.6 nominal
Cooling:	Oil pump with oil cooler
Oil heater:	2 kW
Max gear oil temp:	80°C
Oil cleanliness:	-/15/12 ISO 4406

Table 2-7: Gearbox data

## 2.11 Generator Bearings

The bearings are greased and grease is supplied continuously from an automatic lubrication unit when the nacelle temperature is above -10°C. The yearly grease flow is approximately 2,400 cm<sup>3</sup>/year.

## 2.12 High Speed Shaft Coupling

The flexible coupling transmits the torque from the gearbox high speed output shaft to the generator input shaft. The flexible coupling is designed to minimize misalignments between gearbox and generator. The coupling consists of two composite discs and an intermediate tube with two aluminium flanges and a glass fibre tube. The coupling is fitted to 3-armed hubs on the brake disc and the generator hub.

High Speed Shaft Coupling	
Type Description	VK 420

Table 2-8: High speed shaft coupling data

## 2.13 Yaw System

The yaw system is designed to keep the turbine upwind when the operating mode is RUN or PAUSE. The nacelle is mounted on the yaw plate, which is bolted to the turbine tower. The yaw bearing system is a plain bearing system with built-in friction. Asynchronous yaw motors with brakes enable the nacelle to rotate on top of the tower.

The VMP controller receives information of the wind direction from the wind sensor. Automatic yawing is deactivated when the mean wind speed is below 3 m/s.

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

Table 2-9: Yaw system data

Yaw Gear	
Type	Non-locking combined worm gear and planetary gearbox Electrical motor brake
Motor	1.5 kW, 6 pole, asynchronous
Number of yaw gears	6
Ratio Total (4 planetary stages)	1,120 : 1
Rotational Speed at Full Load	Approx. 1 rpm at output shaft

Table 2-10: Yaw gear data

## 2.14 Crane

The nacelle houses the service crane. The crane is a single system chain hoist.

Crane	
Lifting Capacity	Max. 800 kg

Table 2-11: Crane data

## 2.15 Tower Structure (Onshore)

Tubular towers with flange connections, certified according to relevant type approvals, are available in different standard heights. Magnets provide load support in a horizontal direction and internals, such as platforms, ladders, etc.,

are supported vertically (i.e. in the gravitational direction) by a mechanical connection.

The hub heights listed include a distance from the foundation section to the ground level of approximately 0.6 m depending on the thickness of the bottom flange and a distance from the tower top flange to the centre of the hub of 1.95 m.

Tower Structure	
Type Description	Conical tubular
Hub Heights	80 m/105 m
Material	S355 (A709/A572-50)
Weight	80 m IEC 2A 160 metric tons* 105 m IEC 2A 245 metric tons**

Table 2-12: Tower structure (Onshore) data

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

## 2.16 Nacelle Base-Frame 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 which can be opened from inside the nacelle to access the roof and from outside to access the nacelle. The nacelle cover is mounted on the girder structure. Access from the tower to the nacelle is through the yaw system.

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

The nacelle bedplate carries the crane beams through vertical beams positioned along the site of the nacelle. Lower beams of the girder structure are connected at the rear end.

The rear part of the bedplate serves as foundation for controller panels, cooling system and transformer.

Type Description	Material
Nacelle Cover	GRP
Base Frame Front	SG cast iron
Base Frame Rear	Welded Grid Structure

Table 2-13: Nacelle base-frame and cover data

## 2.17 Cooling

The cooling systems for the main components in the turbine shown below are all placed inside the nacelle and therefore conditioned by nacelle air. The transformer is conditioned by ambient air as it is placed in the air intake. The mass flow of air through the nacelle is mainly driven by the generator external fan and the gear oil cooler fans which lead the heated air out of the nacelle.

Component	Cooler type	Internal heating at low temperature
Nacelle	Forced air	No (yes LT/off shore)
Hub/nose cone	Natural air	No (yes LT/off shore)
Gear	Forced oil/air	Yes
Generator	Forced air/air	Yes
Slip rings	Forced air/air	Yes
Transformer	Forced air	No (heat source)
VCS	Forced water/air	No (heat source)
VRUS	Forced water/air	No (heat source)
VMP section	Forced air/air	Yes
Hydraulics	Forced air	Yes

All other heat generating systems are also equipped with fans and or coolers but are considered as minor contributors to nacelle thermodynamics.

## 2.18 Generator Cooling

The generator cooling system consists of an air to air cooler mounted on the top of the generator and two internal fans and one external fan. All the fans can run at high or low speed (1800/3600 rpm.).

Generator Cooling	
Air Inlet Temp. – External:	35°
Nominal Air Flow – Internal:	2.2 m <sup>3</sup> /s
Nominal Air Flow – External:	1.95 m <sup>3</sup> /s
Cooling Capacity	75 kW

Table 2-14: Cooling, generator data

## 2.19 Converter Cooling

The converter cooling system consists of a water pump that circulates the cooling water through the converter modules and a water cooler with a two-speed fan.

Converter Cooling	
Nominal Water Flow	Approx. 45 l/min (50% glycol)
Water Inlet Pressure	Max 2.0 bar
Water Inlet Temperature	Max. 56 °C
Cooling Capacity	10 kW

Table 2-15: Cooling, converter data

### 2.19.1 Gearbox- and Hydraulic Cooling

The gearbox cooling system consists of two oil circuits and two oil coolers. The first circuit is equipped with a mechanically driven oil pump and oil cooler with built-in thermo bypass valve and the second circuit is equipped with an electrically driven oil pump and oil cooler.

Gearbox Cooling	
<b>Gear Oil Cooler 1 (Mechanically driven oil pump)</b>	
Nominal Oil Flow	72 l/min
Oil Inlet Pressure	80 °C
Air Inlet Temperature	45 °C
Nominal Air Flow	1.5 m <sup>3</sup> /s
Cooling Capacity	32 kW
<b>Gear Oil Cooler 2 (Electrically driven oil pump)</b>	
Nominal Oil Flow	105 l/min
Oil Inlet Temp.	80 °C
Air Inlet Temp.	45 °C
Nominal Air Flow	3.2 m <sup>3</sup> /s
Cooling Capacity	60 kW

Table 2-16: Cooling, gearbox data

The combined lubrication/cooling system is driven by a mechanical pump, mounted on the gear. This pumps oil, whenever gear is rotating. The cooling pump circuit is electric, and only activated when the mechanical circuit cannot meet the cooling demand.

<b>Hydraulic Cooling</b>	
<b>Nominal Water Flow</b>	Approx. 50 l/min (50% glycol)
<b>Water Inlet Pressure</b>	Max 2.0 bar
<b>Water Inlet Temperature</b>	Max. 53 °C
<b>Cooling Capacity</b>	12 kW

*Table 2-17: Cooling, hydraulic data*

### 2.19.2 Transformer Cooling

The transformer is equipped with forced air cooling. The ventilator consists of six fans, located below the transformer leading the cooling air to locations beneath and between the HV and LV windings of the transformer.

<b>Transformer Cooling</b>	
<b>Nominal Air Flow</b>	1470 m <sup>3</sup> /h
<b>Air Inlet Temperature</b>	Max. 30°C

*Table 2-18: Cooling, transformer data*

### 2.19.3 Nacelle Cooling

Heated air generated by mechanical and electrical equipment is removed from the nacelle by the 3 oil cooler fans and the generator cooling fan. The airflow enters the nacelle through louver dampers in the weather shield underneath the nacelle. The fans can run at low or high speed depending on the temperature in the nacelle, gear and generator.

<b>Nacelle Cooling</b>	
<b>Nominal Airflow</b>	7.3 m <sup>3</sup> /s
<b>Air Inlet Temperature</b>	Max. 40°C

*Table 2-19: Cooling, nacelle data*

### 3 Electrical Design

#### 3.1 Generator (VCUS – 60 Hz)

The generator is a 3-phase asynchronous generator with wound rotor, which is connected to the Vestas Converter Unity System (VCUS) via a slip ring system. The generator is an air-to-air cooled generator with an internal and external cooling circuit. The external circuit uses air from the nacelle and exhausts it out through the rear end of the nacelle.

The generator has six poles. The generator is wound with form windings in both rotor and stator. The stator is connected in star at low power and delta at high power. The rotor is connected in star and is insulated from the shaft. A slip ring unit is mounted to the rotor for the purpose of the VCUS control.

Generator	
Type Description	Asynchronous with wound rotor, slip rings and VCUS
Rated Power (PN)	1.86 MW
Rated Apparent Power	1.86 MVA (Cosφ = 1.00)
Frequency	60 Hz
Voltage, Generator	690 Vac
Voltage, Converter	480 Vac
Number of Poles	6
Winding Type (Stator/Rotor)	Form/Form
Winding Connection, Stator	Star/Delta
Rated Efficiency (generator only)	> 96.5 %
Power Factor (cos)	1.0
Over Speed Limit acc. to IEC (2 min.)	2,900 rpm
Vibration Level	≤ 1.8 mm/s
Weight	Approx. 8,100 kg
Generator Bearing - Temperature	2 Pt100 sensors
Generator Stator Windings - Temperature	3 Pt100 sensors placed at hot spots and 3 as back-up

Table 3-1: Generator data

#### 3.2 HV Cables

HV cable runs from the transformer in the nacelle down the tower to the switchgear (switchgear not included). The cable is a 4-conductor rubber insulated halogen free cable.

HV Cables	
Type	NTSCGEHXOEU
Cross Section	3x70/70 mm <sup>2</sup>
Rated Voltage	12/20 kV and 20/35 kV depending on the transformer voltage.

Table 3-2: HV cables data

### 3.3 Transformer

The transformer is located in a separate locked room in the nacelle with surge arresters mounted on the high voltage side of the transformer. The transformer is a two winding, three-phase dry-type transformer, which is self-extinguishing. The windings are delta-connected on the high voltage side unless otherwise specified.

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

Transformer	
Type Description	Dry-type cast resin
Primary Voltage	10-33 kV
Rated Apparent Power	2,100 kVA
Secondary Voltage 1	690 V
Rated Power 1 at 1000 V	1,900 kVA
Secondary Voltage 2	480 V
Rated Power 2 at 400 V	200 kVA
Vector Group	Dyn5 (option YNyn0)
Frequency	60 Hz
HV-tappings	± 2 x 2.5 % offload
Inrush Current	6-10 x $\hat{I}_n$ depending on type.
Short-circuit Impedance	7.8 % ±10% @ 690V, 1,900 kVA, 120°C
Insulation Class	F
Climate Class	C2
Environmental Class	E2
Fire behaviour Class	F1

Table 3-3: Transformer data

### 3.4 Converter

The converter controls the energy conversion in the generator. The VCUS converter feeds power from the grid into the generator rotor at sub sync speed and feeds power from the generator rotor to the grid at super sync speed.

<b>Converter</b>	
<b>Rated Slip</b>	12%
<b>Rated RPM</b>	1,344 RPM
<b>Rated Rotor Power (slip=12%, 400V)</b>	185 kW
<b>Rated Grid Current (slip = 12%)</b>	210 A
<b>Rated Rotor Current</b>	101 A
<b>Rated Rotor Current (cos <math>\phi</math>= 1.0, slip = 12%)</b>	576 A

Table 3-4: Converter data

### 3.5 AUX System

The AUX System is supplied from the 690/480 V outlet from the HV transformer. All motors, pumps, fans and heaters are supplied from this system.

All 110 V power sockets are supplied from a 690/110 V transformer.

<b>Power Sockets</b>	
<b>Single Phase</b>	110 V (20 A)
<b>Three Phase</b>	690 V (16 A)

Table 3-5: AUX system data

### 3.6 Wind Sensors

The turbine is equipped with 2 ultrasonic wind sensors with built in heaters.

<b>Wind Sensors</b>	
<b>Type</b>	FT702LT
<b>Principle</b>	Acoustic Resonance
<b>Built in Heat</b>	99 W

Table 3-6: Wind sensor data

### 3.7 VMP (Vestas Multi Processor) Controller

The turbine is controlled and monitored by the VMP5000 control system.

VMP5000 is a multiprocessor control system comprised of 4 main processors (Ground, Nacelle, Hub and Converter) interconnected by an optical-based 2.5 Mbit ArcNet network.

I/O modules are connected to CAN interface modules by a serial digital bus, CTBus.

**The VMP5000 controller serves the following main functions:**

- Monitoring and supervision of overall operation
- Synchronizing of the generator to the grid during connection sequence in order to limit the inrush current
- Operating the wind turbine during various fault situations
- Automatic yawing of the nacelle
- OptiTip® - blade pitch control
- Noise emission control
- Monitoring of ambient conditions
- Monitoring of the grid
- Monitoring of the smoke detection system

VMP5000 is built from the following main modules:

Module	Function	Network
CT3601	Main processor. Control and monitoring (ground, nacelle and hub)	ArcNet, CAN
CT318	Main processor. Converter control and monitoring	ArcNet
CT3218	Counter/encoder module. RPM and Azimuth measurement	CTBus
CT3134 Digital in CT3153 Digital out	24 VDC digital input/output. 4 channels configurable for either input or output.	CTBus
CT3215	2 Ch. RS 422/485 port. Serial interface for e.g. wind sensors.	CTBus
CT3220 Pigiback C	2 Ch. Analogue input 0.24 mA (Configurable).	CTBus
CT3220 Pigiback F	3 Ch. PT100 interface module. 4 wire pt100 measurement technology	CTBus
CT218	Operator Panel. RS422 interface	-----

Table 3-7: VMP controller data

### 3.8 Uninterruptible Power Supply (UPS)

The UPS is equipped with AC/DC DC/AC converter (double conversions), which receives power from battery cells in the same cabinet as the UPS. During grid outage, the UPS will supply the specified component with 230V AC.

The back-up time for the UPS system is proportional to the power consumption. Actual back-up time may vary.

UPS		
<b>Battery Type</b>	Valve-Regulated Lead Acid (VRLA)	
<b>Rated Battery Voltage</b>	2 x 8 x 12 V (192 V)	
<b>Converter Type</b>	Double conversion online	
<b>Rated Output Voltage</b>	230 V AC	
<b>Rated Output Voltage</b>	230 V AC	
<b>Converter Input</b>	230 V +/-20%	
<b>Back-up Time*</b>	Controller system	30 seconds
	Safety Systems	35 minutes
<b>Re-charging Time</b>	Typical	Approx. 2.5 hours

Table 3-8: UPS data

**NOTE** \* For alternative back-up times, please consult Vestas!

## 4 Turbine Protection Systems

### 4.1 Braking Concept

The main brake on the turbine is aerodynamic. Braking the turbine is done by feathering the three blades. Each blade can be feathered individually to slow the turbine in an emergency stop.

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

### 4.2 Short Circuit Protections

Breakers	Generator / Q8 ABB S7H 1600 690 V	Controller / Q15 ABB S3X 690 V	VCS-VCUS / Q7 ABB S5H 400 480 V
<b>Breaking Capacity</b> $I_{cu}, I_{cs}$	25, 20 KA	75, 75 KA	40, 40 KA
<b>Making Capacity</b> $I_{cm}$ (415V Data)	143 KA	440 KA	143 KA
<b>Thermo Release</b> $I_{th}$	1600 A	100 A	400 A
<b>Magnetic Release</b> $I_m$	9.6 KA	1.0 KA	1600 A

Table 4-1: Short circuit protection data

### 4.3 Overspeed Protection

The generator RPM and the main shaft RPM are registered by inductive sensors and calculated by the wind turbine controller in order to protect against over-speed and rotating errors.

The turbine is also equipped with a VOG (Vestas Overspeed Guard), which is an independent computer module measuring the rotor RPM, and in case of an overspeed situation the VOG activates full feathering of the three blades independently of the turbine controller in the turbine.

Overspeed Protection	
VOG Sensors Type	Inductive
Trip Levels	19.36 (Rotor RPM)/2,110 (Generator RPM)

Table 4-2: Overspeed protection data

### 4.4 Lightning System

The Lightning System (LS) consists of three main parts.

- Lightning receptors
- Down conducting system
- Earthing System

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

Table 4-3: Lightning design parameters

**NOTE** Lightning system is designed according to IEC (see 7.7). Lightning strikes are considered force majeure, i.e. damage caused by lightning strikes is not warranted by Vestas.

### 4.5 Earthing (also known as grounding)

A separate set of documents describe the earthing system in detail, depending on the type of foundation the turbine has been installed on.

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

## 4.6 Corrosion Protection

Classification of corrosion categories for atmospheric corrosion is according to ISO 9223:1992

Corrosion Protection	External Areas	Internal Areas
Nacelle	C5	C3 and C4 Climate strategy: Heating the air inside the nacelle compared to the outside air temperature lowers the relative humidity and helps ensure a controlled corrosion level.
Hub	C5	C3
Tower	C5-I	C3

*Table 4-4: Corrosion protection data for nacelle, hub and tower*

## 5 Safety

The safety specifications in Section 5 provide limited general information about the safety features of the turbine and are not a substitute for Buyer and its agents taking all appropriate safety precautions, including but not limited to (a) complying with all applicable safety, operation, maintenance, and service agreements, instructions, and requirements, (b) complying with all safety-related laws, regulations, and ordinances, (c) conducting all appropriate safety training and education and (d) reading and understanding all safety-related manuals and instructions. See section 5.14 Manuals and Warnings, p. 22 for additional guidance.

### 5.1 Access

Access to the turbine from the outside is through the bottom of the tower. The door is equipped with a lock. Access to the top platform in the tower is by a ladder or lift (optional). Access to the nacelle from the top platform is by ladder. Access to the transformer room in the nacelle is equipped with a lock. Unauthorized access to electrical switch boards and power panels in the turbine is prohibited according to IEC 60204-1 2006.

### 5.2 Escape

In addition to the normal access routes, alternative escape routes from the nacelle are through the crane hatch or from the roof of the nacelle.

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

Escape from the tower lift is by ladder.

### 5.3 Rooms/Working Areas

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

### 5.4 Floors, Platforms, Standing and Working Places

There is one floor per tower section.

There are places to stand at various locations along the ladder.

The floors have anti-slip surfaces.

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

### 5.5 Climbing Facilities

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

Rest platforms are provided at intervals of 9 metres along the tower ladder between platforms.

There are anchorage points in the tower, nacelle, hub and on the roof for attaching a fall arrest harness.

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

Anchorage points are coloured yellow and are calculated and tested to 22.2 kN

## **5.6 Moving Parts, Guards and Blocking Devices**

Moving parts in the nacelle are shielded.

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

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

## **5.7 Lighting**

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

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

## **5.8 Noise**

When the turbine is out of operation for maintenance, the sound level in the nacelle is below 80 dB(A). In operation mode ear protection is required.

## **5.9 Emergency Stop**

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

## **5.10 Power Disconnection**

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

## **5.11 Fire Protection/First Aid**

A 5 kg CO<sub>2</sub> fire extinguisher must be located in the nacelle at the left yaw gear. The location of the fire extinguisher, and how to use it, must be confirmed before operating the turbine.

A first aid kit must be placed by the wall at the back end of the nacelle. The location of the first aid kit, and how to use it, must be confirmed before operating the turbine.

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

## **5.12 Warning Signs**

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

### **5.13 Offshore Installation**

In addition to the safety equipment mentioned above, offshore turbines are provided with a fire extinguisher and first aid box at the bottom of the tower, and a survival kit on the second platform in the tower.

### **5.14 Manuals and Warnings**

Vestas OH&S manual and manuals for operation, maintenance and service of the turbine provide additional safety rules and information for operating, servicing or maintaining the turbine.

## **6 Environment**

### **6.1 Chemicals**

Chemicals used in the turbine are evaluated according to Vestas Wind Systems A/S Environmental system certified according to ISO 14001:2004.

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

## 7 Approvals, Certificates and Design Codes

### 7.1 Type Approvals

The turbine is type certified according to the certification standards listed below:

Standard	Conditions	Hub Height
IEC SoC	IEC Class 2A	80 m
	IEC Class 2A	105 m

Table 7-1: Type approvals data

### 7.2 Design Codes – Structural Design

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

Design Codes - Structural Design	
<b>Nacelle and Hub</b>	IEC 61400-1:2005 EN 50308
<b>Tower</b>	IEC 61400-1:2005 Eurocode 3

Table 7-2: Structural design codes

### 7.3 Design Codes - Mechanical Equipment

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

Design Codes – Mechanical Equipment	
<b>Gear</b>	Designed in accordance to rules in ISO 81400-4
<b>Blades</b>	DNV-OS-J102 IEC 1024-1 IEC 60721-2-4 IEC 61400 (Part 1, 12 and 23) IEC WT 01 IEC DEFU R25 ISO 2813 DS/EN ISO 12944-2

Table 7-3: Mechanical equipment design codes

## 7.4 Design Codes - Electrical Equipment

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

<b>Design Codes – Electrical Equipment</b>	
<b>High Voltage ac circuit breakers</b>	IEC 60056
<b>High Voltage testing techniques</b>	IEC 60060
<b>Power Capacitors</b>	IEC 60831
<b>Insulating bushings for ac voltage above 1kV</b>	IEC 60137
<b>Insulation co-ordination</b>	BS EN 60071
<b>AC Disconnectors and earth switches</b>	BS EN 60129
<b>Current Transformers</b>	IEC 60185
<b>Voltage Transformers</b>	IEC 60186
<b>High Voltage switches</b>	IEC 60265
<b>Disconnectors and Fuses</b>	IEC 60269
<b>Flame Retardant Standard for MV Cables</b>	IEC 60332
<b>Transformer</b>	IEC 60076-11
<b>Generator</b>	IEC 60034
<b>Specification for sulphur hexafluoride for electrical equipment</b>	IEC 60376
<b>Rotating electrical machines</b>	IEC 34
<b>Dimensions and output ratings for rotating electrical machines</b>	IEC 72 & IEC 72A
<b>Classification of insulation, materials for electrical machinery</b>	IEC 85
<b>Safety of machinery – Electrical equipment of machines</b>	IEC 60204-1

Table 7-4: Electrical equipment design codes

## 7.5 Design Codes - I/O Network System

The distributed I/O network system has been developed and tested with regard to, but not limited to, the following main standards:

Design Codes – I/O Network System	
<b>Salt Mist Test</b>	IEC 60068-2-52
<b>Damp Head, Cyclic</b>	IEC 60068-2-30
<b>Vibration Sinus</b>	IEC 60068-2-6
<b>Cold</b>	IEC 60068-2-1
<b>Enclosure</b>	IEC 60529
<b>Damp Head, Steady State</b>	IEC 60068-2-56
<b>Vibration Random</b>	IEC 60068-2-64
<b>Dry Heat</b>	IEC 60068-2-2
<b>Temperature Shock</b>	IEC 60068-2-14
<b>Free Fall</b>	IEC 60068-2-32

*Table 7-5: I/O Network system design codes*

## 7.6 Design Codes - Lightning Protection

The LPS is designed according to Lightning Protection Level (LPL) I:

Design Codes – Lightning Protection	
<b>Designed according to</b>	IEC 62305-1: 2006
	IEC 62305-3: 2006
	IEC 62305-4: 2006
<b>Non Harmonized Standard and Technically Normative Documents</b>	IEC/TR 61400-24:2002

*Table 7-6: Lightning protection design codes*

## 7.7 Design Codes – Earthing

The Vestas Earthing System design is based on and complies with the following international standards and guidelines:

- IEC 62305-1 Ed. 1.0: Protection against lightning – Part 1: General principles.
- IEC 62305-3 Ed. 1.0: Protection against lightning – Part 3: Physical damage to structures and life hazard.
- IEC 62305-4 Ed. 1.0: Protection against lightning – Part 4: Electrical and electronic systems within structures.

- IEC/TR 61400-24. First edition. 2002-07. Wind turbine generator systems - Part 24: Lightning protection.
- IEC 60364-5-54. Second edition 2002-06. Electrical installations of buildings - Part 5-54: Selection and erection of electrical equipment – Earthing arrangements, protective conductors and protective bonding conductors.
- IEC 61936-1. First edition. 2002-10. Power installations exceeding 1kV a.c.- Part 1: Common rules.

## 8 Colour and Surface Treatment

### 8.1 Nacelle Colour and Surface Treatment

Surface Treatment of Vestas Nacelles	
<b>Standard Nacelle Colours</b>	RAL 7035 (light grey) RAL 9010 (pure white)
<b>Gloss</b>	According to ISO 2813

Table 8-1: Surface treatment, nacelle

### 8.2 Tower Colour and Surface Treatment

Surface Treatment of Vestas Tower Section		
	External:	Internal:
<b>Tower Colour Variants</b>	RAL 7035 (light grey) RAL 9010 (pure white) – only Onshore	RAL 9001 (cream white)
<b>Gloss</b>	50-75% UV resistant	Maximum 50%

Table 8-2: Surface treatment, tower

### 8.3 Blades Colour

There is a range of available blade colours depending on country specific requirements.

Blades Colour	
<b>Blade Colour Variants</b>	RAL 7035 (Light Grey), RAL 9010 (White), RAL 7038 (Agate Grey)
<b>Tip-End Colour Variants</b>	RAL 2009 (Traffic Orange), RAL 3000 (Flame Red), RAL 3020 (Traffic Red)
<b>Gloss</b>	< 20%

Table 8-3: Colours, blades

## 9 Operational Envelope and Performance Guidelines

Actual climatic and site conditions have many variables and must be considered in evaluating actual turbine performance. The design and operating parameters set forth in this section do not constitute warranties, guarantees, or representations as to turbine performance at actual sites.

**NOTE** As evaluation of climate and site conditions is complex, it is needed to consult Vestas for every project.

### 9.1 Climate and Site Conditions

Values refer to hub height:

Extreme Design Parameters		
Wind Climate	IEC 2A	IEC 3A
Ambient Temperature Interval (Normal Temperature Turbine)	-30° to +50 °C	
Extreme Wind Speed (10 min. average)	42.5 m/s	37.5 m/s
Survival Wind Speed (3 sec. gust)	59.5 m/s	52.5 m/s

*Table 9-1: Extreme design parameters*

Average Design Parameters		
Wind Climate	IEC 2A	IEC 3A
Wind Speed	8.5 m/s	7.5 m/s
A-factor	9.59 m/s	8.46 m/s
Form Factor, c	2.0	2.0
Turbulence Intensity acc. to IEC 61400-1, including Wind Farm Turbulence (@15 m/s – 90% quantile)	18%	
Wind Shear	0.20	
Inflow Angle (vertical)	8°	

*Table 9-2: Average design parameters*

### 9.1.1 Complex Terrain

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

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

### 9.1.2 Altitude

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

Above 1000 m special considerations must be taken regarding e.g. HV installations and cooling performance. Consult Vestas for further information.

### 9.1.3 Wind Farm Layout

Turbine spacing to be evaluated site-specifically. Spacing in any case not below three rotor diameters (3D).

## DISCLAIMER

As evaluation of climate and site conditions is complex, consult Vestas for every project. If conditions exceed the above parameters Vestas must be consulted!

## 9.2 Operational Envelope – Temperature and Wind

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

Operational Envelope – Temperature and Wind	
Ambient Temperature Interval (Normal Temperature Turbine)	-20° to +40° C
Cut-in (10 min. average)	3.5 m/s
Cut-out (100 sec. exponential average)	25 m/s
Re-cut in (100 sec. exponential average)	20 m/s

Table 9-3: Operational envelope - temperature and wind

## 9.3 Operational Envelope - Grid Connection \*

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

Operational Envelope - Grid Connection		
Nominal Phase Voltage	$U_{P, nom}$	400 V
Nominal Frequency	$f_{nom}$	60 Hz

Table 9-4: Operational envelope - grid connection

The Generator and the converter will be disconnected if:

	<b>U<sub>P</sub></b>	<b>U<sub>N</sub></b>
<b>Voltage above 110 % of nominal for 60 sec.</b>	440 V	759 V
<b>Voltage above 113.5 % of nominal for 0.2 sec.</b>	454 V	783 V
<b>Voltage above 120 % of nominal for 0.08 sec.</b>	480 V	828 V
<b>Voltage below 90 % of nominal for 60 sec.</b>	360 V	621 V
<b>Voltage below 85 % of nominal for 0.4 sec.</b>	340 V	586 V
<b>Voltage below 75 % of nominal for 0.08 sec.</b>	300 V	517 V
<b>Frequency is above [Hz] for 0.2 sec.</b>	62 Hz	
<b>Frequency is below [Hz] for 0.2 sec.</b>	57 Hz	

*Table 9-5: Generator and converter disconnecting values*

**NOTE** \* Over the lifetime of the turbine, grid dropouts are to be limited to no more than once a month on average as calculated over one year.

## 9.4 Performance – Own Consumption

The consumption of electrical power by the wind turbine is defined as consumption when the wind turbine is not producing energy (generator is not connected to the grid). This is defined in the control system as Production Generator (zero).

The following components have the largest influence on the power consumption of the wind turbine:

<b>Own Consumption</b>	
<b>Hydraulic Motor</b>	18.6 kW
<b>Yaw Motors 6 x 1.75 kW</b>	10.5 kW
<b>Oil Heating 3 x 0.76 kW</b>	2.3 kW
<b>Air Heaters 3 x 3.4 kW</b>	10.2 kW
<b>Oil Pump for Gearbox Lubrication</b>	3.5 kW
<b>HV Transformer located in the nacelle has a no-load loss of</b>	Max. 3.9 kW

*Table 9-6: Own consumption data*

## 9.5 Operational Envelope - Conditions for Power Curve, Noise Levels, $C_p$ & $C_t$ Values (at Hub Height)

See Appendix 1 for  $C_p$  &  $C_t$  values, Appendix 2 for power curve and Appendix 3 for noise level.

Conditions for Power Curve, Noise Levels, $C_p$ & $C_t$ Values (at Hub Height)	
Wind Shear	0.10 - 0.16 (10 min. average)
Turbulence Intensity	8 - 12% (10 min. average)
Blades	Clean
Rain	No
Ice/Snow on Blades	No
Leading Edge	No damage
Terrain	IEC 61400-12-1
Inflow Angle (Vertical)	$0 \pm 2^\circ$
Grid Frequency	$60 \pm 0.5$ Hz

Table 9-7: Conditions for power curve, noise levels,  $C_p$  &  $C_t$  values

## 10 Drawings

### 10.1 Structural Design - Illustration of Outer Dimensions

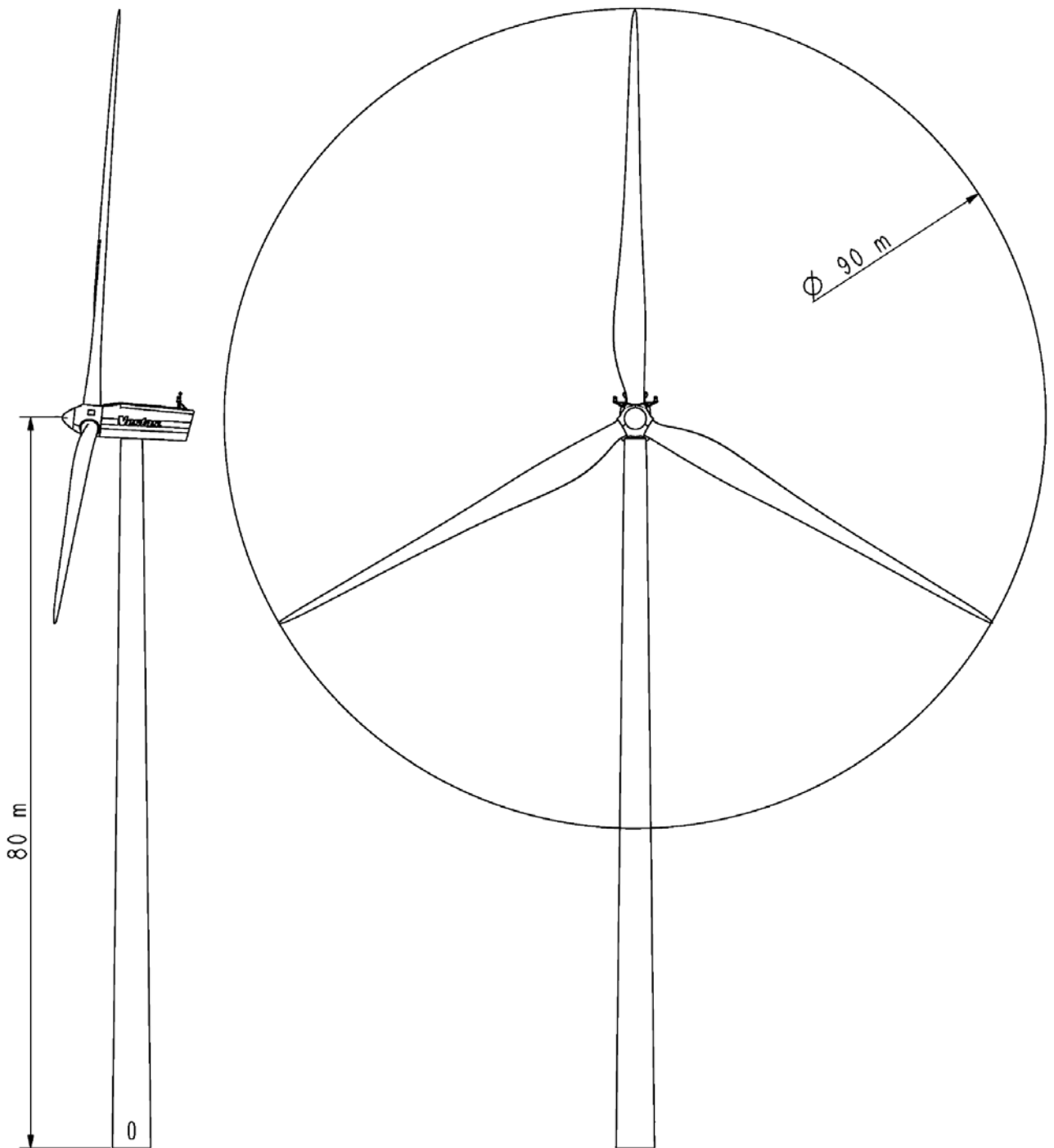


Figure 10-1: Illustration of outer dimensions – structure (Drawing no. 956042)

## 10.2 Structural Design - Side View Drawing

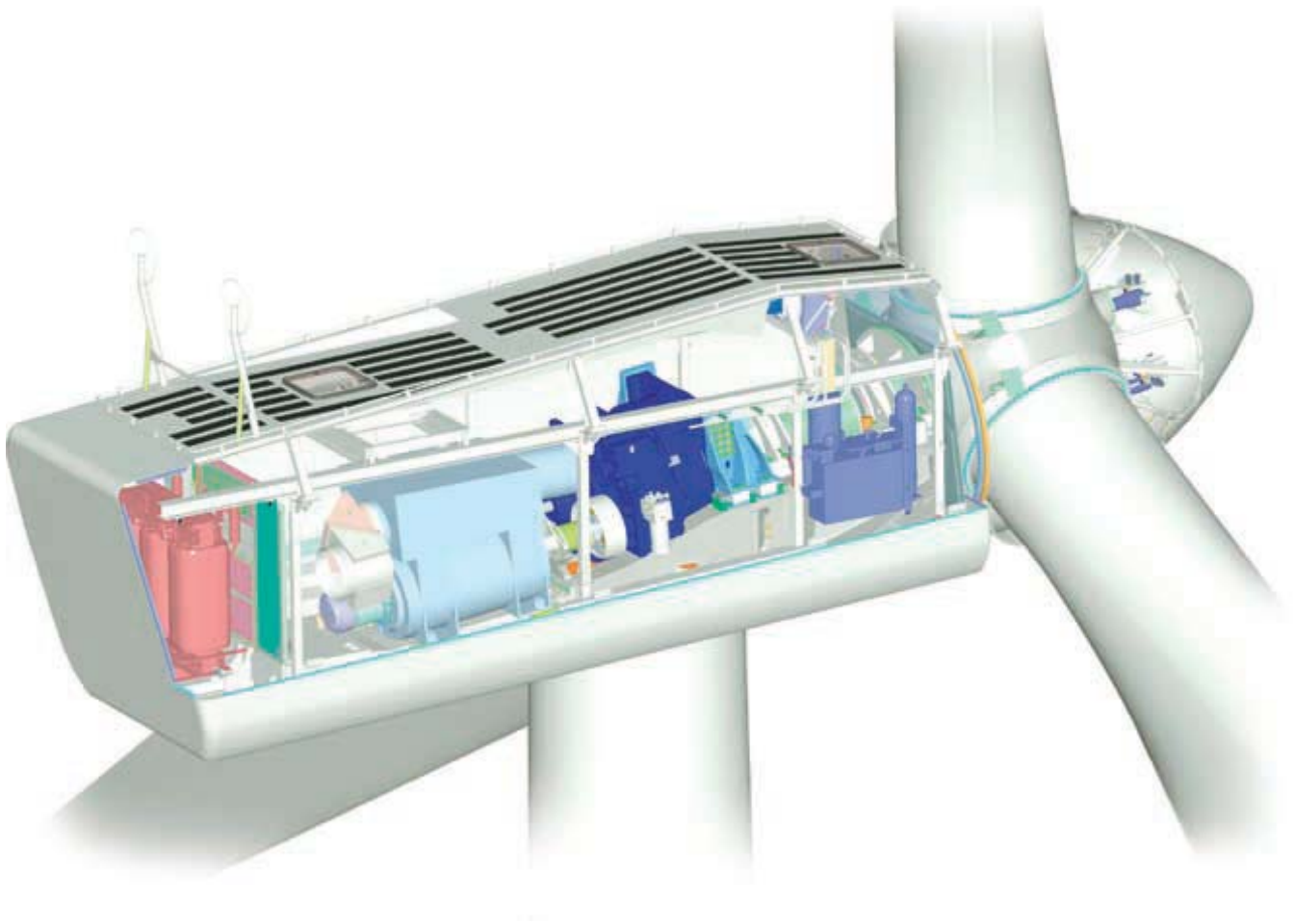


Figure 10-2: Side view drawing

### 10.3 Electrical Design – Main Wiring 60 Hz

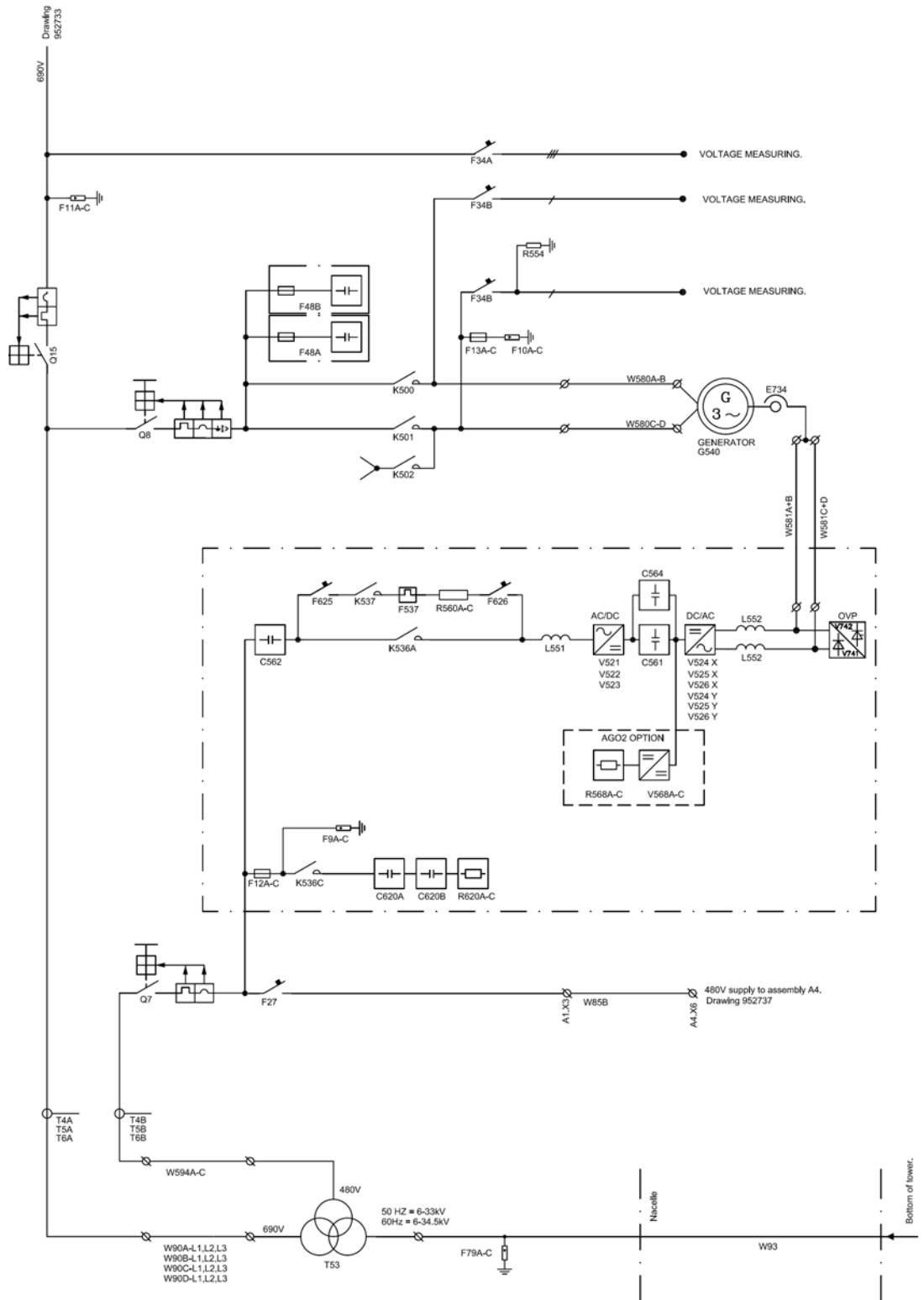


Figure 10-3: Main wiring 60 Hz

## 11 General Reservations, Notes and Disclaimers

- These general specifications apply to the current version of the V90 wind turbine. Updated versions of the V90 wind turbine, which may be manufactured in the future, may have general specifications that differ from these general specifications. In the event that Vestas supplies an updated version of the V90 wind turbine, Vestas will provide updated general specifications applicable to the updated version.
- Periodic operational disturbances and generator power de-rating may be caused by combination of high winds, low voltage or high temperature.
- Vestas recommends that the 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.
- The estimated power curve for the different estimated noise levels (sound power levels) is for wind speeds at 10 minute average value at hub height and perpendicular to the rotor plane.
- All listed start/stop parameters (e. g. wind speeds and temperatures) are equipped with hysteresis control. This can, in certain borderline situations, result in turbine stops even though the ambient conditions are within the listed operation parameters.
- The earthing system must comply with the minimum requirements from Vestas, and be in accordance with local and national requirements, and codes of standards.
- Lightning strikes are considered force majeure, i.e. damage caused by lightning strikes is not warranted by Vestas.
- For the avoidance of doubt, this document 'General Specifications' is not, and does not contain, any guarantee, warranty and/or verification of the power curve and noise (including, without limitation, the power curve and noise verification method). Any guarantee, warranty and/or verification of the power curve and noise (including, without limitation, the power curve and noise verification method) must be agreed to separately in writing.

## 12 Appendices

### 12.1 Performance – $C_p$ & $C_t$ Values

Performance – $C_p$ & $C_t$ Values – Air Density 1.225 kg/m <sup>3</sup>		
Wind Speed	$C_p$ (Mode 0)	$C_t$ (Mode 0)
m/s	[-]	[-]
3	0.4246	0.8470
4	0.4836	0.7962
5	0.4841	0.8007
6	0.4841	0.8008
7	0.4841	0.8009
8	0.4839	0.7805
9	0.4696	0.6990
10	0.4343	0.6047
11	0.3775	0.4915
12	0.2907	0.3556
13	0.2287	0.2725
14	0.1831	0.2153
15	0.1489	0.1740
16	0.1227	0.1432
17	0.1023	0.1196
18	0.0861	0.1012
19	0.0732	0.0866
20	0.0628	0.0748
21	0.0542	0.0652
22	0.0472	0.0572
23	0.0413	0.0506
24	0.0363	0.0450
25	0.0322	0.0403

Table 12-1:  $C_p$  &  $C_t$  values

## 12.2 Performance - Estimated Power Curves

At 1000V / 400V, low voltage side of the high voltage transformer.

Wind speed at hub height, 10 min average.

### 12.2.1 Power Curve, Mode 0

Wind speed [m/s]	1.225	0.97	1	1.03	1.06	1.09	1.12	1.15	1.18	1.21	1.24	1.27
3	18	12	12	13	13	14	15	16	16	17	18	19
4	88	63	66	69	72	75	78	81	84	87	90	93
5	202	153	159	165	171	176	182	188	194	199	205	211
6	363	280	289	299	309	319	328	338	348	358	367	377
7	589	459	474	490	505	520	536	551	566	582	597	612
8	888	695	718	741	764	786	809	831	854	877	899	922
9	1226	965	995	1026	1057	1088	1119	1149	1180	1211	1241	1271
10	1548	1235	1273	1311	1349	1387	1426	1461	1496	1531	1564	1594
11	1758	1492	1531	1569	1607	1645	1684	1705	1726	1747	1764	1775
12	1808	1700	1719	1737	1755	1773	1791	1796	1801	1805	1809	1811
13	1815	1789	1793	1798	1803	1807	1812	1813	1814	1815	1815	1815
14	1815	1812	1813	1813	1814	1814	1815	1815	1815	1815	1815	1815
15	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815
16	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815
17	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815
18	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815
19	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815
20	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815
21	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815
22	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815
23	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815
24	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815
25	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815	1815

Figure 12-1: Power curve, mode 0

## 12.3 Noise Levels

### 12.3.1 Noise Curve V90 – 1.8 MW, 60 Hz, Mode 0

Sound Power Level at Hub Height: Noise mode 0		
Conditions for Sound Power Level:	Measurement standard IEC 61400-11 ed. 2 2002 Wind shear: 0.16 Max. turbulence at 10 meter height: 16% Inflow angle (vertical): $0 \pm 2^\circ$ Air density: $1.225 \text{ kg/m}^3$	
Hub Height	80 m	105 m
$L_{wA}$ @ 4 m/s (10 m above ground) [dBA]	94.6	95.5
Wind speed at hh [m/sec]	5.6	5.8
$L_{wA}$ @ 5 m/s (10 m above ground) [dBA]	99.4	100.3
Wind speed at hh [m/sec]	7.0	7.3
$L_{wA}$ @ 6 m/s (10 m above ground) [dBA]	102.3	102.6
Wind speed at hh [m/sec]	8.4	8.7
$L_{wA}$ @ 7 m/s (10 m above ground) [dBA]	103.1	103.3
Wind speed at hh [m/sec]	9.8	10.2
$L_{wA}$ @ 8 m/s (10 m above ground) [dBA]	103.5	103.5
Wind speed at hh [m/sec]	11.2	11.7
$L_{wA}$ @ 9 m/s (10 m above ground) [dBA]	103.5	103.5
Wind speed at hh [m/sec]	12.6	13.1
$L_{wA}$ @ 10 m/s (10 m above ground) [dBA]	103.5	103.5
Wind speed at hh [m/sec]	14.0	14.6
$L_{wA}$ @ 11 m/s (10 m above ground) [dBA]	103.5	103.5
Wind speed at hh [m/sec]	15.3	16.0
$L_{wA}$ @ 12 m/s (10 m above ground) [dBA]	103.5	103.5
Wind speed at hh [m/sec]	16.7	17.5
$L_{wA}$ @ 13 m/s (10 m above ground) [dBA]	103.5	103.5
Wind speed at hh [m/sec]	18.1	18.9

Figure 12-2: Noise curve, mode 0