ECOCAS Wind Farm

(Esgair Cwmowen Central and South)

Volume 4

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ECOCAS Wind Farm

October 2009

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INDEPENDENT POWERSYSTEMS

Volume 4 – Appendix 1

Turbine Specifications

Class I
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General Specification
V90 – 3.0 MW VCS 50 Hz

Vestas
No.1 in Modern Energy

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Buyer acknowledges that these general specifications are for buyer's informational purposes only and do not create or constitute a warranty, guarantee, promise, commitment, or other representation by supplier, all of which are disclaimed by supplier except to the extent expressly provided by supplier in writing elsewhere.

Please refer to section 11 General Reservations, Notes and Disclaimers, p. 39 for general reservations, notes, and disclaimers applicable to these general specifications.

1 General Description

The Vestas V90 - 3.0 MW wind turbine is a pitch regulated upwind turbine with active yaw and a three-blade rotor. The Vestas V90 - 3.0 MW turbine has a rotor diameter of 90 m with a generator rated at 3.0 MW. The turbine utilizes the OptiTip® and OptiSpeed™ concepts. 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 even in high wind speeds. At low wind speeds, the OptiTip® and OptiSpeed™ systems work together to maximize the power output by giving the optimal RPM and pitch angle, which also helps to minimize the sound emission from the turbine.

2 Mechanical Design

2.1 Rotor

The V90-3.0 MW is equipped with a 90 meter rotor consisting of three blades and the hub. The blades are controlled by a microprocessor pitch control system called OptiTip®. 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^2
Rotational Speed Static, Rotor	16.1 rpm
Speed, Dynamic Operation Range	8.6 – 18.4
Rotational Direction	Clockwise (front view)
Orientation	Upwind
Tilt	6°
Blade Coning	4°
Number of Blades	3
Aerodynamic Brakes	Full feathering

Table 2-1: Rotor Data

2.2 Blades

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

Blades	
Type Description	Airfoil shells bonded to supporting beam
Blade Length	44 m
Material	Fibreglass reinforced epoxy and carbon fibres
Blade Connection	Steel roots inserted
Air Foils	Risø P + FFA
Largest Chord	3.512 m
Weight per blade	App. 6700 kg

Table 2-2: Blades Data

2.3 Blade Bearing

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

Blade Bearing	
Lubrication	Grease, automatic lubrication pump

Table 2-3: Blade Bearing Data

2.4 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 with the piston rod mounted to the blade 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
Cylinder	Ø125/80 – 760
Number	1 per blade
Range	-5º to 90º

Table 2-4: Pitch System Data

Hydraulic System	
Main Pump	Radial Piston Pump 45 ccm (variable)
Pressure	260 bar
Filtration	3my (absolute)

Table 2-5: Hydraulic System Data

2.5 Hub

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

Hub	
Material	Cast iron EN GJS 400-18U-LT / EN1560
Weight	App. 8850 kg.

Table 2-6: Hub Data

2.6 Main Bearing

The main bearing is integrated into the gearbox. The rotor hub is connected directly to the gearbox input shaft, which is connected to the main bearing.

The main bearing is lubricated by the same continuous forced oil lubrication and external oil sump system as the gearbox.

Main Bearing	
Type Description	Double row tapered roller bearing
Lubrication	Pressure lubrication with oil, external oil sump
Oil Filter	3 µm / 10 µm

Table 2-7: Main Bearing Data

2.7 Gearbox

The main gear converts the low-speed rotation of the rotor to high-speed generator rotation. The gear unit is a combination of a 2-stage planetary gear and a 1-stage helical gear. It is a compact design without main shaft and torque supporters.

The low speed input shaft is bolted directly to the hub without the use of a traditional main shaft and the gear housing is bolted to the bedplate.

The disc brake is mounted on the high speed shaft. The gearbox lubrication system is a pressure-fed system without the use of an integrated oil sump.

Gearbox	
Type Description	2 planetary stage + 1 helical stage
Gear House Material	Cast

Gearbox	
Ratio	1:104.56
Mechanical Power	3300 kW
Weight	App. 22800 kg
Lubrication	Pressure lubrication with oil, external oil sump
Gear Oil Tank Capacity	App. 550 l
Oil Flow	Max. 190 l/min
Oil Inlet Temperature	Max. 62 ºC
Offline Filter / Inline Filter	3 µm / 10 µm
Shaft Seals	Labyrinth and contact seal

Table 2-8: Gearbox Data

2.8 Generator Bearings

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

2.9 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 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.

2.10 Yaw System

The yaw system is designed with active yawing and a robust plain yaw bearing with some minor friction between the yaw rim and the PETP gliding plate.

The yaw gears are 4-stage planetary gears. When the yaw system is not yawing the yaw motors are locked with a brake (self-locking system). The yaw system will not yaw by influence of the wind only.

Yaw System	
Type	Plain bearing system with built in friction
Material	Forged yaw ring heat-treated. Plain bearings PETP
Yawing Speed	0.47˚/sec.

Table 2-9: Yaw System Data

Yaw Gear	
Type	4-step planetary gear with motor brake and torque limiter
Number of yaw gears	6
Ratio Total (4 planetary stages)	1391 : 1
Rotational Speed at Full Load	1 rpm at output shaft

Table 2-10: Yaw Gear Data

2.11 Crane

The nacelle houses the internal Safe Working Load (SWL) service crane. The crane is a single system chain hoist.

Crane	
Lifting Capacity	Max. 800 kg

Table 2-11: Crane Data

2.12 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 (i.e. in the gravitational direction) by a mechanical connection. The smooth tower design reduces the required steel thickness, rendering the tower lighter compared one with internals solely welded to the tower shells.

2.12.1 Onshore Towers

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 1.95m.

Onshore Towers	
Type Description	Conical tubular
Hub Heights	80 m/105 m
Material	S355 (A709/A572-50)
Weight	175 t (80m IEC1a)* / 275 t (105m IEC2a) **

Table 2-12: Tower Structure (Onshore) Data

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

2.12.2 Offshore Towers

Offshore towers are project specific.

2.13 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. The skylights can both 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, 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 six yaw-gears are bolted to the front nacelle bedplate.

The crane beams are attached to the top structure. The lower beams of the girder structure are connected at the rear end. The rear part of the bedplate serves as the foundation for controller panels, cooling system and transformer. The nacelle cover is mounted on the nacelle bedplate.

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

Table 2-13: Nacelle Base-Frame and Cover data

2.14 Cooling

2.14.1 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 flow. The cooling liquid removes heat from the generator and converter unit through a radiator placed at the end of the nacelle where 2 fans cool the liquid. In addition to the generator, converter unit and radiator, the circulation system includes an electrical pump and a 3-way thermostatic valve.

Generator Cooling	
Nominal Water Flow	App. 150 l/min (50% glycol)
Water Inlet Pressure	Max. 2.0 bar
Water Inlet Temperature	Max. 56 ºC
Cooling Capacity	75 kW

Table 2-14: Cooling, Generator Data

Converter Cooling	
Nominal Water Flow	App. 50 l/min (50% glycol)
Water Inlet Pressure	Max 2.0 bar
Water Inlet Temperature	Max. 56 ºC
Cooling Capacity	15 kW

Table 2-15: Cooling, Converter Data

2.14.2 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 through a plate heat exchanger and from the hydraulic unit through a radiator placed at the end of the nacelle where 2 fans cool the liquid. In addition to the gearbox plate heat exchanger, hydraulic unit and radiator, the circulation system includes an electrical pump and a 3-way thermostatic valve.

Gearbox Cooling	
Nominal Water Flow	App. 175 l/min (50% glycol)
Water Inlet Pressure	Max 2.0 bar
Water Inlet Temperature	Max. 53°C
Cooling Capacity	70 kW

Table 2-16: Cooling, Gearbox Data

Hydraulic Cooling	
Nominal Water Flow	App. 50 l/min (50% glycol)
Water Inlet Pressure	Max 2.0 bar
Water Inlet Temperature	Max. 53 ºC
Cooling Capacity	12 kW

Table 2-17: Cooling, Hydraulic Data

2.14.3 Transformer Cooling

The transformer is equipped with forced air cooling. The ventilator consists of a central fan, located below the service floor with six pipes leading to locations beneath and between the HV and LV windings of the transformer. The fan can run at low or high speed depending on the transformer temperature.

Transformer Cooling	
Nominal Air Flow	0.6 / 1.3 m^3/s
Air Inlet Temperature	Max. 40°C

Table 2-18: Cooling, Transformer Data

2.14.4 Nacelle Cooling

Hot air generated by mechanical and electrical equipment is removed from the nacelle by two fans. 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.

Nacelle Cooling	
Nominal Airflow	4.4 / 6.8 m^3/s
Air Inlet Temperature	Max. 40°C

Table 2-19: Cooling, Nacelle Data

3 Electrical Design

3.1 Generator

The generator is a 3-phase asynchronous generator with wound rotor, which is connected to the Vestas Converter System (VCS) via a slip ring.

The generator housing is built with a cylindrical jacket and channels, which circulate cooling liquid around the generator internal stator housing.

The generator has four poles. The generator is wound with form windings in both rotor and stator. The stator is connected in star at low power and in 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 making for the purpose of double fed control.

Generator	
Type Description	Double fed asynchronous with wound rotor and slip rings
Rated Power [P_N]	3.0 MW
Rated Apparent Power [S_N]	3125 kVA (Cosφ = 0.96)
Frequency [f_N]	50 Hz
Voltage, Stator [U_{NS}]	3 x 1000 V
Voltage, Rotor [U_{NR}]	3 x 400 V
Number of Poles	4
Winding Type (Stator/Rotor)	Form/Form
Winding Connection, Stator	Star/Delta
Rated Efficiency (generator only)	> 97.5 %
Power Factor, default (cos)	1.0
Possible cos Φ Regulation, Capacitive/Inductive	0.98/0.96
Rated RPM / Rated Slip	1680 RPM / 12 %
Over Speed Limit acc. to IEC (2 min.)	2900 RPM
Vibration Level	≤ 1.8 mm/s
Weight	App. 8600 kg
Generator Bearing - Temperature	2 Pt100 sensors
Generator Stator Windings - Temperature	3 Pt100 sensors placed at hot spots and 3 as back-up
Enclosure	IP54

Table 3-1: Generator Data

3.2 HV Cables

A HV cable runs from the transformer in the nacelle down the tower to the switchgear located in the bottom of the tower. The cable is a 4-conductor rubber insulated halogen free and flame retardant cable.

HV Cables	
Type	(N)TSCGEHXOEU
Cross Section	$3x70/70mm^2$
Rated Voltage	12/20 (24) kV or 20/35 (42) kV depending on the transformer voltage.

Table 3-2: HV Cables Data

3.3 HV Transformer

The step-up 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 1000V and a tapping at 400V and are star-connected. The 1000V and 400V systems in the nacelle are a TN-system, which means the star point is connected to earth.

HV Transformer	
Type Description	Dry-type cast resin
Primary Voltage [U_N]	10-33 kV
Rated Apparent Power [S_N]	3140 kVA
Secondary Voltage 1 [$U_{NS}1$]	3 x 1000 V
Rated Apparent Power 1 at 1000 V [S_N1]	2835 kVA
Secondary Voltage 2 [$U_{NS}2$]	3 x 400 V
Rated Apparent Power 2 at 400 V [S_N2]	305 kVA
Vector Group	Dyn5 (option YNyn0)
Frequency	50 Hz
HV-tappings	± 2 x 2.5 % offload
Inrush Current	6-10 x $\hat{I}_n$ depending on type.
Short-circuit Impedance	8% $^{+10}_{-0}$% @ 1000 V, 2835 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 to provide a better performance and larger operation area.

The converter consists of 2 individual parts: grid-inverter and rotor-inverter. An inverter is able to transform AC signals to DC and also DC signals to AC. The AC side is the front side of the inverter and the DC side is the back side. As the converter is connected through its DC connection, it is referred to as a “back-to-back” converter..

Converter	
Rated Rotor power (slip=12%, 400V)	328 kW
Rated Grid current (slip = 12%)	476 A
Rated Rotor Current	979 A
Rated Rotor current (low noise, slip = 6%)	1158 A
Rated Rotor current (cos φ= 0.98$_{CAP}$)	1086 A
Max. Slip	28%
Max. Rotor Power	675 kW
Max. Grid Current (Voltage – 10 %)	1082 A
Rated DC-link voltage	700 VDC
For high slip 25%-30 % The DC-link is up to	970 VDC
OVP Trigger Voltage:	1050 VDC

Table 3-4: Converter Data

3.5 AUX System

The AUX System is supplied from the 400 V outlet from the HV transformer. All motors, pumps, fans and heaters are supplied from this system.

All 230 V consumers are supplied from a 400/230 V transformer.

Power Sockets	
Single Phase (Nacelle & Tower)	230 V (10 A)
Three Phase (Nacelle)	3 x 400 V (16 A)

Table 3-5: AUX System Data

3.6 Wind Sensors

The turbine is equipped with 2 ultrasonic wind sensors with no movable parts.

The sensors have built in heaters to minimize interference from ice/snow.

Wind Sensors	
Type	FT702LT
Principle	Acoustic Resonance
Built in Heat	99 W

Table 3-6: Wind Sensor Data

3.7 VMP (Vestas Multi Processor) Controller

The turbine is controlled and monitored by the VMP6000 control system.

VMP6000 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.

In addition to the 4 main processors the VMP6000 consists of a number of distributed I/O modules interconnected by a 500 kbit CAN network

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

The VMP6000 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
- Reactive power control and variable speed operation
- Noise emission control
- Monitoring of ambient conditions
- Monitoring of the grid
- Logging of lightning strikes
- Monitoring of the smoke detection system.

VMP6000 is built from the following main modules:

Module	Function	Network
CT6003	Main Processor. Control and Monitoring (Ground, Nacelle and Hub)	ArcNet, CAN
CT318	Main Processor. Converter Control and Monitoring	ArcNet
CT6050	Blade Sensor Interface. Lightning and load sensor interface module. 1 per blade.	CAN

Module	Function	Network
CT6061	CAN interface for I/O modules	CAN, CTBus
CT6062	CAN interface module including 6 230 VAC digital outputs and 12 230 VAC digital inputs	CAN, CTBus
CT6118	Counter/Encoder module. RPM and Azimuth measurement	CTBus
CT6137	24 VDC digital input/output. 4 channels configurable for either input or output.	CTBus
CT6215	2 Ch. RS 422/485 port. Serial interface for e.g. wind sensors.	CTBus
CT6220	2 Ch. Analogue input 0.24 mA (Configurable).	CTBus
CT6221	3 Ch. PT100 interface module. 4 wire pt100 measurement technology	CTBus
CT6244	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 components with 230V AC.

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

UPS		
Battery Type	Valve-Regulated Lead Acid (VRLA)	
Rated Battery Voltage	2 x 8 x 12 V (192 V)	
Converter Type	Double conversion	
Converter Input	230 V +/-20%	
Rated Output Voltage	230 V AC	
Back-up Time*	Controller system	10 minutes
	Switchgear function (motor release/activation)	10 minutes
	Remote control system	10 minutes
	Internal light in tower and nacelle	1 hour
	Aviation light	1 hour
Re-charging Time	80%	App. 3 hours
	100%	App. 8 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 full feathering the three blades (individual turning of each blade). Each blade has a hydraulic accumulator as power supply 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 push buttons.

4.2 Short Circuit Protections

Breakers	**Generator / Q8** **ABB E2N E-2000** **1000 V**	**Controller / Q22** **ABB T2L160** **400 V**	**VCS / Q7** **ABB T5L630** **400 V**
Breaking Capacity, I_{cu}, I_{cs}	30 kA@1000 IEC	85 kA @415V IEC	120 kA @415V IEC
Making Capacity, I_{cm}	63 kA	187 kA @415V IEC	264 kA @415V IEC
Thermo Release, I_{th}	0.8-2.0 kA	112-160A	252-630A
Magnetic Release, I_{m}	3.0-30 kA	1.6 kA	0.945-7.56 kA

Table 4-1: Short Circuit Protection Data

4.3 Overspeed Protection

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

The turbine is 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)/2024 (Generator RPM)

Table 4-2: Overspeed Protection Data

4.4 Lightning Protection of Blades, Nacelle, Hub & Tower

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

- Lightning receptors.
- Down conducting system. A system to conduct the lightning current down through the wind turbine to help avoid or minimise damage to the LPS system itself or other parts of the wind turbine.
- Protection against over-voltage and over-current.
- Shielding against magnetic and electrical fields.
- 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 Protection Design Parameters

NOTE Lightning strikes are considered force majeure, i.e. damage caused by lightning strikes is not warranted by Vestas.

4.5 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 park.

The Vestas Earthing System is adapted to the different types of foundation a turbine can be erected on. A separate set of documents describe the earthing system in detail, depending on the type of foundation the turbine is erected on.

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 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.

4.6 Corrosion Protection

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

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 (Onshore) C5-M (Offshore)	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, and (c) conducting all appropriate safety training and education.

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 prevented 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, from the spinner by opening the nose cone, or from the roof of the nacelle. Rescue equipment is placed in the turbine.

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

Escape from the tower lift is by ladder.

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

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-, 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.

5.5 Climbing Facilities

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

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

All 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 Lights

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 noise level in the nacelle is below 80 dB(A). In operation mode ear protection is required.

5.9 Emergency Stop

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

5.10 Power Disconnection

The turbine is equipped with breakers 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

It is required that a handheld 5-6 kg CO_2 fire extinguisher is located in the nacelle during service and maintenance. A bracket for the fire extinguisher is located at the left yaw gear.

It is also a requirement that a first aid kit is located in the nacelle during service and maintenance.

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 which should 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.

- Cooling 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 WT01 DIBt Richtlinie für Windkraftanalagen	IEC Class IA	80
	IEC Class IIA	105

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	
Nacelle and Hub	IEC 61400-1:2005 EN 50308
Tower	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	
Gear	Designed in accordance to rules in ISO 81400-4
Blades	DNV-OS-J102 IEC 1024-1 IEC 60721-2-4 IEC 61400 (Part 1, 12 and 23) IEC WT 01 IEC DEFU R25 ISO 2813 DS/EN ISO 12944-2

Table 7-3: 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:

Design Codes – Electrical Equipment	
High Voltage ac circuit breakers	IEC 60056
High Voltage testing techniques	IEC 60060
Power Capacitors	IEC 60070
Insulating bushings for ac voltage above 1kV	IEC 60137
Insulation co-ordination	BS EN 60071
AC Disconnectors and earth switches	BS EN 60129
Current Transformers	IEC 60185
Voltage Transformers	IEC 60186
High Voltage switches	IEC 60265
Disconnectors and Fuses	IEC 60269
Flame Retardant Standard for MV Cables	IEC 60332
Transformer	IEC 60071/IEC 60076
Generator	IEC 60034
Specification for sulphur hexafluoride for electrical equipment	IEC 60376
Rotating electrical machines	IEC 34
Dimensions and output ratings for rotating electrical machines	IEC 72 & IEC 72A
Classification of insulation, materials for electrical machinery	IEC 85
Safety of machinery – Electrical equipment of machines	IEC 60204-1

Table 7-4: Electrical Equipment Design Codes

7.5 Design Codes – Cables

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

Design Codes - Cables	
LV Cables	IEC 227

Design Codes - Cables	
Conductors for Insulated Cables	IEC 60228
Power Cables with Extruded Insulation; to 36 kV	IEC 60502
Power Cables with Extruded Insulation; Test Methods	IEC 60502
Power Cables with Extruded Insulation; Calculation of Permissible Short Circuit Currents	IEC 60949

Table 7-5: Cables Design Codes

7.6 Design Codes - I/O Network System

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

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

Table 7-6: I/O Network System Design Codes

7.7 Design Codes - Lightning Protection

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

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

Table 7-7: Lightning Protection Design Codes

7.8 Design Codes – Earthing

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

Design Codes – Earthing
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.

Table 7-8: Earthing Design Codes

8 Colour and Surface Treatment

8.1 Nacelle Colour and Surface Treatment

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

Table 8-1: Surface Treatment, Nacelle

8.2 Tower Colour and Surface Treatment

Surface Treatment of Vestas Tower Section		
	External:	**Internal:**
Tower Colour Variants	RAL 7035 (light grey) RAL 9010 (pure white) – only Onshore	RAL 9001 (cream white)
Gloss	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	
Blade Colour Variants	RAL 7035 (Light Grey), RAL 9010 (White), RAL 7038 (Agate Grey)
Tip-End Colour Variants	RAL 2009 (Traffic Orange), RAL 3000 (Flame Red), RAL 3020 (Traffic Red)
Gloss	< 20%

Table 8-3: Colour, Blades

9 Operational Envelope and Performance Guidelines

Actual climatic 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.

9.1 Climate and Site Conditions

Values refer to hub height:

Extreme Design Parameters		
	IEC IA	**IEC IIA**
Ambient Temperature Interval (Normal Temperature Turbine)	-40° to +50° C	
Extreme Wind Speed (10 min. average)	50 m/s	42.5 m/s
Survival Wind Speed (3 sec. gust)	70 m/s	59.5 m/s

Table 9-1: Extreme Design Parameters

Average Design Parameters		
Wind Climate	**IEC IA**	**IEC IIA**
Wind Speed	10.0 m/s	8.5 m/s
A-factor	11.28 m/s	9.59 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).

NOTE As evaluation of climate and site conditions is complex it is recommended to consult Vestas for every project. If conditions exceed the above parameters Vestas has to 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 are determined by the sensors and control system of the turbine.

Operational Envelope - Grid Connection		
Nominal Phase Voltage	**[U_{NP}]**	577 V
Nominal Frequency	**[f_N]**	50 Hz

Table 9-4: Operational Envelope - Grid Connection

The Generator and the Converter will be disconnected if:

	[U_P]
Voltage above 110 % of nominal for 60 sec.	635 V
Voltage above 113.5 % of nominal for 0.2 sec.	655 V
Voltage above 120 % of nominal for 0.08 sec.	692 V
Voltage below 90 % of nominal for 60 sec.	519 V
Voltage below 85 % of nominal for 0.4 sec.	490 V
Voltage below 75 % of nominal for 0.08 sec.	433 V
	[f]
Frequency is above 102 % of nominal for 0.2 sec.	51 Hz
Frequency is below 94 % of nominal for 0.2 sec.	47 Hz

Table 9-5: Generator and Converter Disconnecting Values

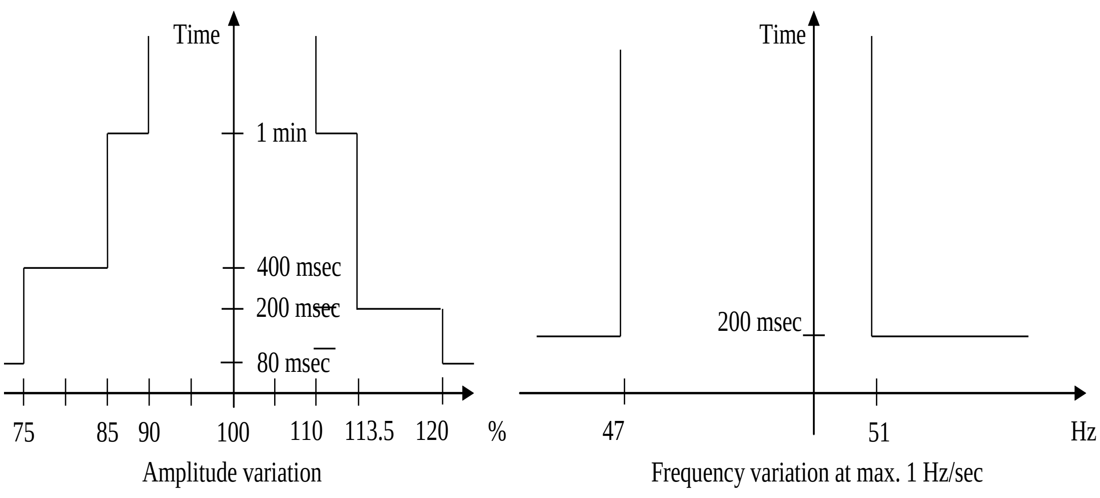


Figure 9-1: Amplitude and Frequency Variation

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

9.4 Operational Envelope – Reactive Power Capability

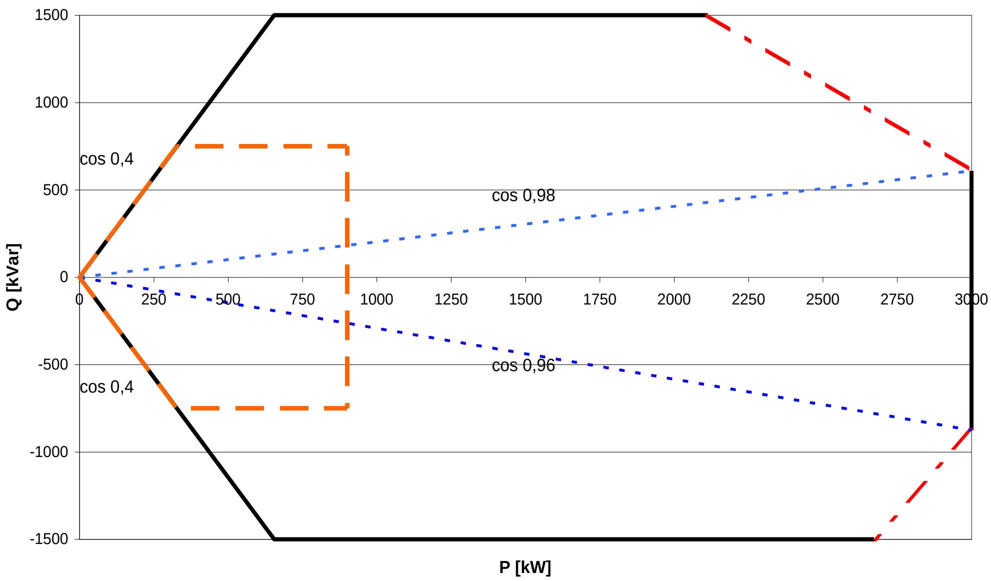


Figure 9-2: Reactive Power Capability

The capability of the V90-3.0 MW wind turbine to perform reactive power control is shown in the above chart. Note that the above chart only applies at nominal voltage.

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

Reactive power is produced by the rotor converter, therefore traditional capacitors are not used in the turbine.

Please note that the area marked with orange dashed line indicates that the generator can be in either star or delta, depending on the actual conditions.

At maximum active and reactive power, the turbine reduces either active or reactive power depending on which type of power has priority (red dashed line). E.g. if reactive power has priority, the active power is reduced.

9.5 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 0 (zero).

The following components 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.):

Own Consumption	
Hydraulic Motor	22.0 kW
Yaw Motors 6 x 2.2 kW	13.2 kW
Oil Heating 3 x 1.0 kW	3.0 kW
Air Heaters 2 x 9.0 kW	18.0 kW
Oil Pump for Main Bearing / Gearbox Lubrication	7.5 kW
Controller including heating elements for the hydraulics and all controllers	Max. app. 3.5 kW
HV Transformer located in the nacelle has a no-load loss of	Max. 4.4 kW

Table 9-6: Own Consumption Data

9.6 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 curves and Appendix 3 for noise levels.

Conditions for Power Curve, Noise Levels, C_p & C_t Values (at Hub Height)	
Wind Shear	0 - 0.3 (10 min. average)
Turbulence Intensity	6 - 12% (10 min. average)
Blades	Clean
Rain	No
Ice/Snow on Blades	No
Leading Edge	No damage
Terrain	IEC 61400-12-1
Inflow (slope):	0 - 5°
Grid Frequency	50 ±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

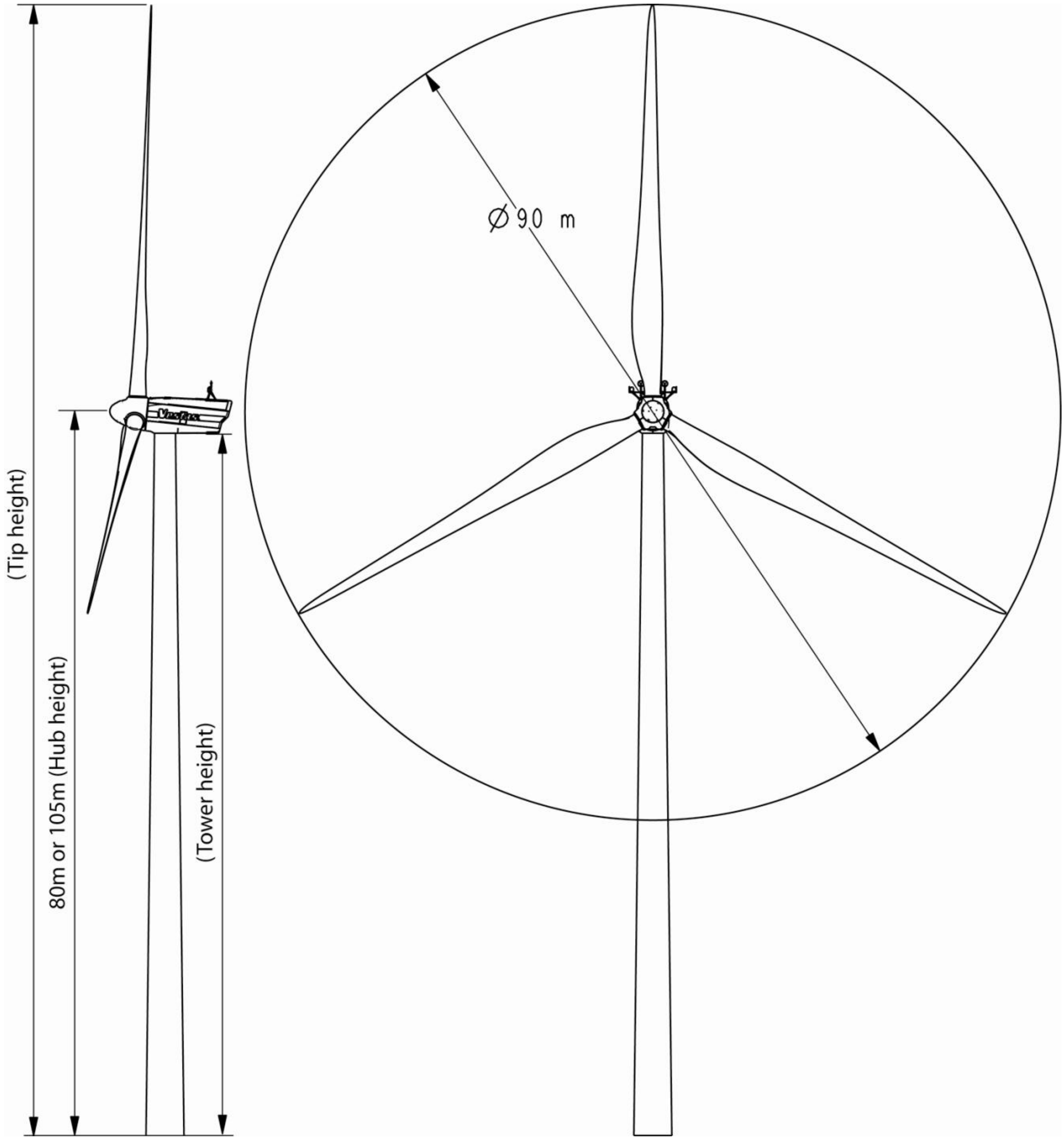
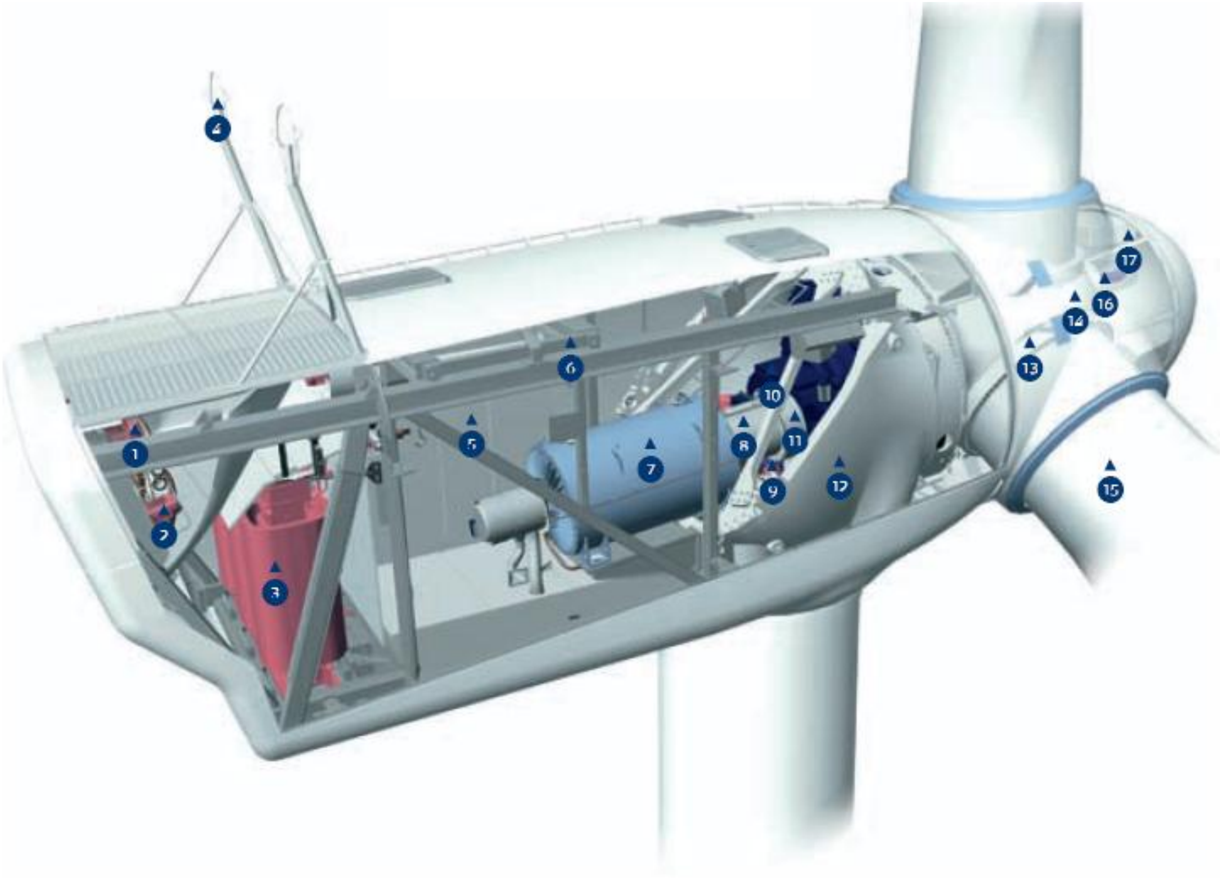


Figure 10-1: Illustration of Outer Dimensions - Structure

10.2 Structural Design - Side View Drawing



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

Figure 10-2: Side View Drawing

10.3 Structural Design - Centre of Gravity

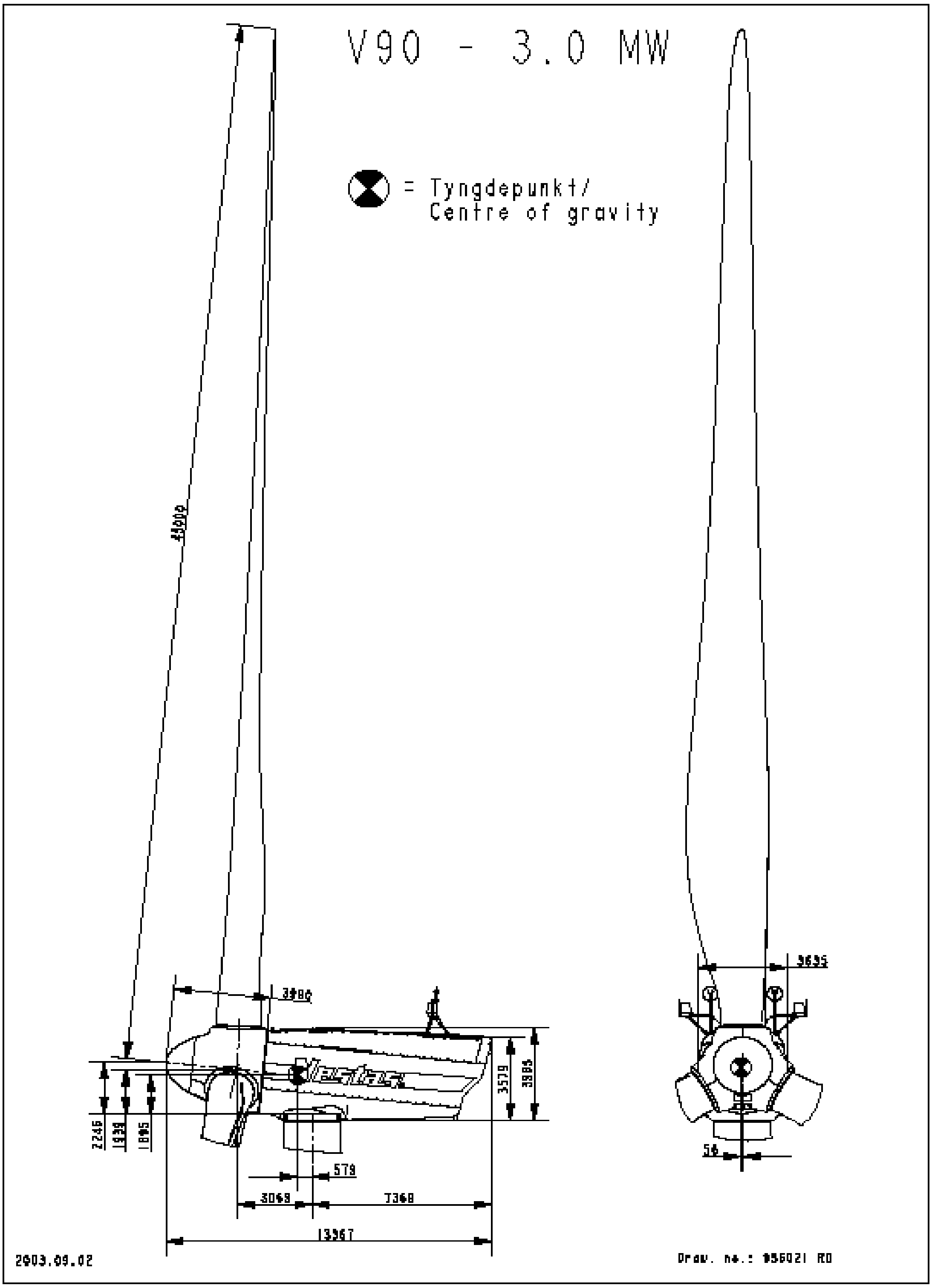
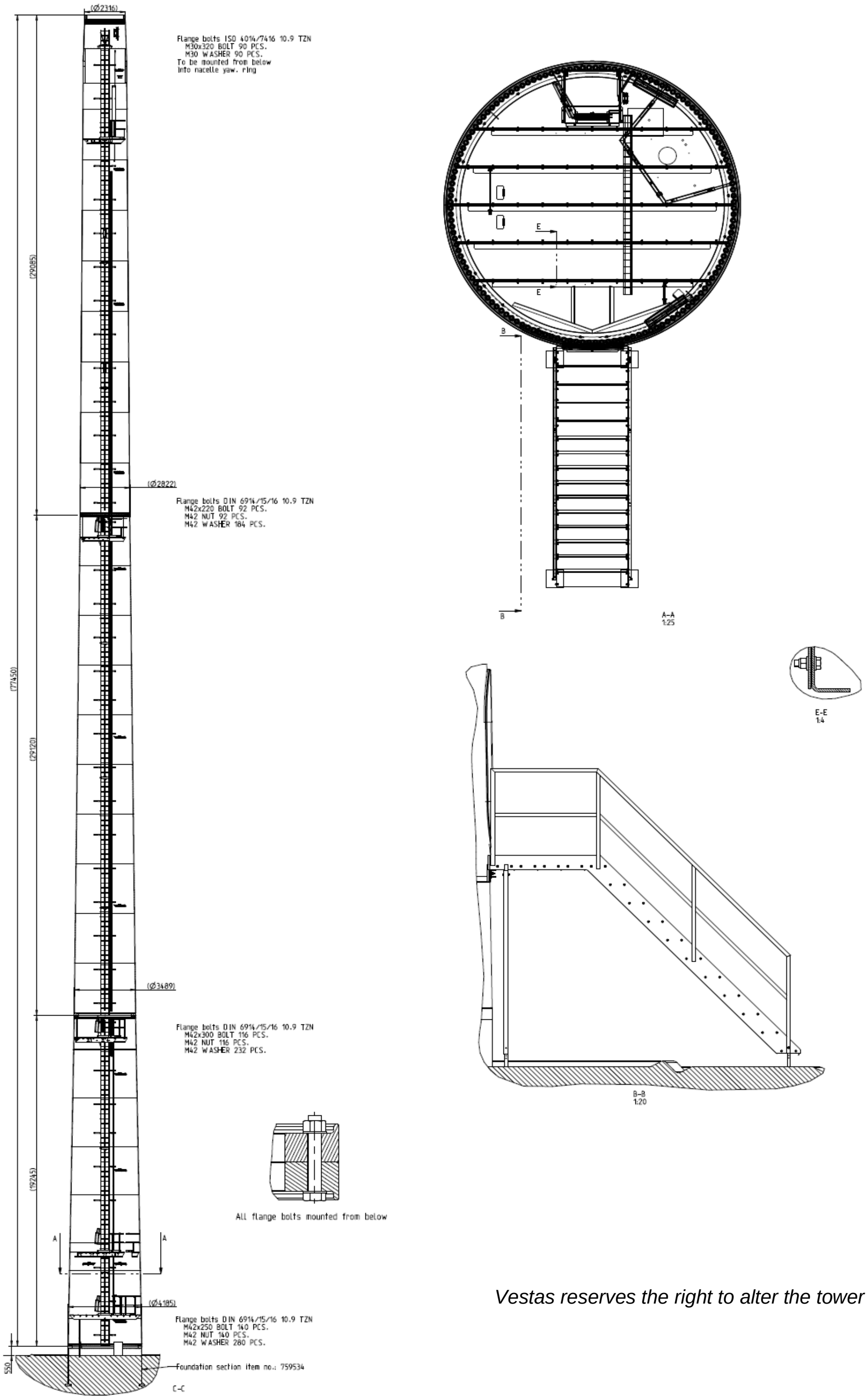


Figure 10-3: Centre of Gravity

10.4 Structural Design - Tower Drawing (Example)



Vestas reserves the right to alter the tower accordingly.

Figure 10-4: Tower Design (Example, 3 MW, Onshore)

NOTE Once the foundation is completed, the position of the tower door is fixed to ensure a safe position in relation to the electrical cabinets inside the tower.

10.5 Electrical Design – Main Wiring 50 Hz

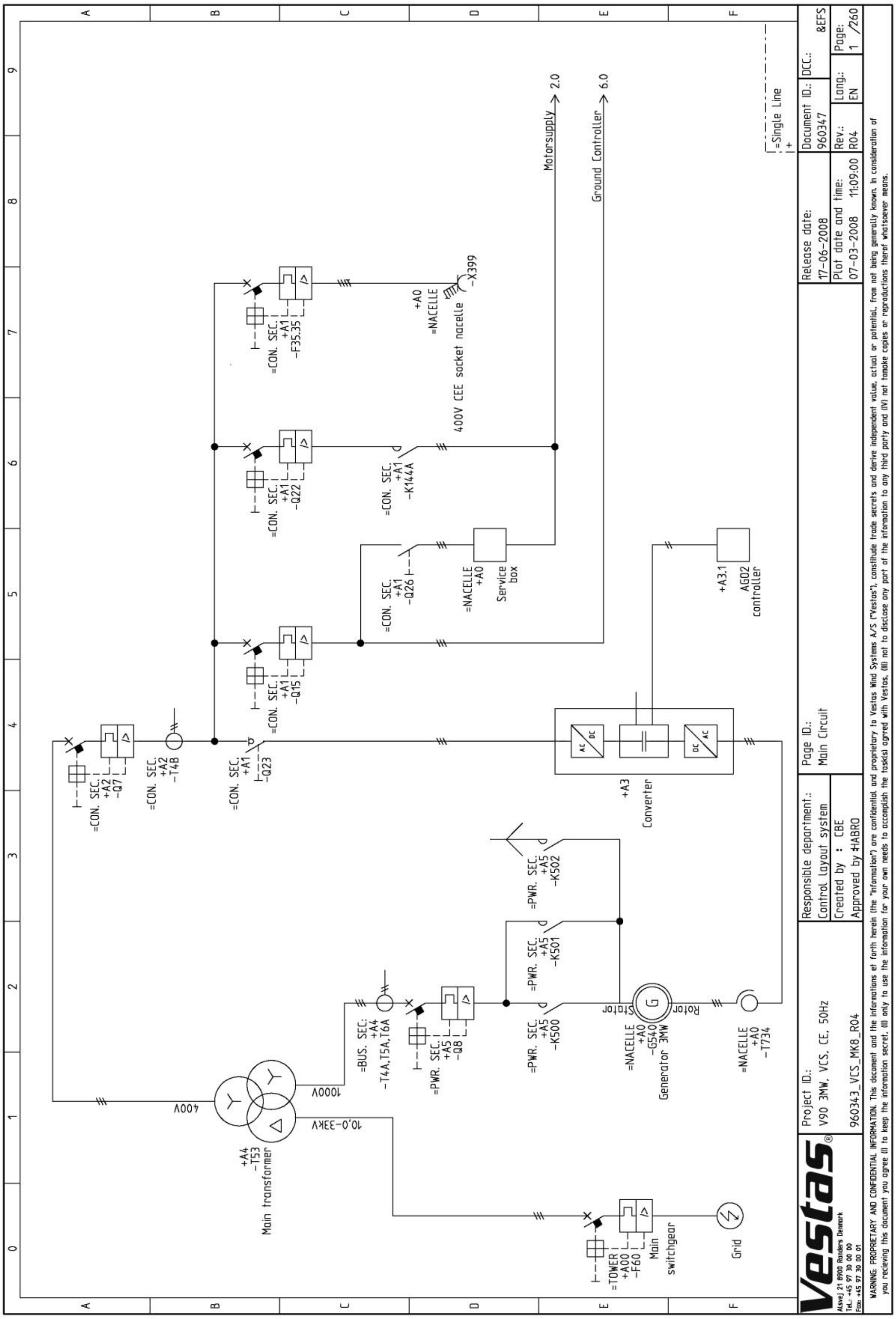


Figure 10-5: Main Wiring 50 Hz

11 General Reservations, Notes and Disclaimers

- Vestas OptiSpeed™ technology is not available in the United States of America and Canada.
- 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 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.
- 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 General Specification 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^3		
Wind Speed	**C_p (Mode 0)**	**C_t (Mode 0)**
m/s	[-]	[-]
4	0.309	0.912
5	0,390	0.879
6	0.419	0.852
7	0.435	0.851
8	0.444	0.830
9	0.448	0.810
10	0.439	0.739
11	0.414	0.660
12	0.378	0.578
13	0.331	0.489
14	0.277	0.407
15	0.228	0.327
16	0.188	0.263
17	0.157	0.217
18	0.132	0.181
19	0.112	0.154
20	0.096	0.132
21	0.083	0.114
22	0.072	0.100
23	0.063	0.088
24	0.056	0.078
25	0.049	0.070

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

V90 - 3.0 MW, 50 Hz, Mode 0 - 109.4 dB(A)												
	Air Density [kg/m^3]											
Wind Speed [m/s]	**0.97**	**1**	**1.03**	**1.06**	**1.09**	**1.12**	**1.15**	**1.18**	**1.21**	**1.225**	**1.24**	**1.27**
4	53	56	59	61	64	67	70	72	75	77	78	81
5	142	148	153	159	165	170	176	181	187	190	193	198
6	271	281	290	300	310	319	329	339	348	353	358	368
7	451	466	482	497	512	528	543	558	574	581	589	604
8	691	714	737	760	783	806	829	852	875	886	898	921
9	995	1028	1061	1093	1126	1159	1191	1224	1257	1273	1289	1322
10	1341	1385	1428	1471	1515	1558	1602	1645	1688	1710	1732	1775
11	1686	1740	1794	1849	1903	1956	2010	2064	2118	2145	2172	2226
12	2010	2074	2137	2201	2265	2329	2392	2454	2514	2544	2573	2628
13	2310	2382	2455	2525	2593	2658	2717	2771	2817	2837	2856	2889
14	2588	2662	2730	2790	2841	2883	2915	2940	2958	2965	2971	2981
15	2815	2868	2909	2939	2960	2975	2984	2990	2994	2995	2996	2998
16	2943	2965	2979	2988	2993	2996	2998	2999	2999	3000	3000	3000
17	2988	2994	2997	2998	2999	3000	3000	3000	3000	3000	3000	3000
18	2998	2999	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
19	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
20	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
21	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
22	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
23	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
24	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
25	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000

Figure 12-1: Power Curve, Mode 0

12.2.2 Power Curve, Mode 1

V90 - 3.0 MW, 50 Hz, Mode 1 - 107.8 dB(A)												
	Air Density [kg/m^3]											
Wind Speed [m/s]	**0.97**	**1**	**1.03**	**1.06**	**1.09**	**1.12**	**1.15**	**1.18**	**1.21**	**1.225**	**1.24**	**1.27**
4	53	56	59	61	64	67	70	72	75	77	78	81
5	142	148	153	159	165	170	176	181	187	190	193	198
6	271	281	290	300	310	319	329	339	348	353	358	368
7	451	466	482	497	512	528	543	558	574	581	589	604
8	691	714	737	760	783	806	829	852	875	886	898	921
9	994	1027	1060	1092	1125	1157	1190	1223	1255	1272	1288	1321
10	1330	1373	1416	1460	1503	1546	1589	1632	1675	1696	1718	1761
11	1656	1709	1762	1815	1868	1921	1974	2027	2080	2106	2133	2186
12	1963	2026	2088	2151	2213	2276	2338	2399	2459	2489	2518	2575
13	2258	2329	2400	2470	2539	2605	2666	2723	2774	2797	2818	2856
14	2539	2614	2684	2748	2804	2851	2889	2919	2942	2951	2959	2971
15	2778	2837	2883	2919	2946	2964	2977	2985	2991	2993	2994	2996
16	2925	2953	2971	2983	2990	2994	2997	2998	2999	2999	2999	3000
17	2983	2991	2995	2997	2999	2999	3000	3000	3000	3000	3000	3000
18	2997	2999	2999	3000	3000	3000	3000	3000	3000	3000	3000	3000
19	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
20	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
21	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
22	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
23	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
24	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
25	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000

Figure 12-2: Power Curve, Mode 1

12.2.3 Power Curve, Mode 2

V90 - 3.0 MW, 50 Hz, Mode 2 - 106.8 dB(A)												
	Air Density [kg/m^3]											
Wind Speed [m/s]	**0.97**	**1**	**1.03**	**1.06**	**1.09**	**1.12**	**1.15**	**1.18**	**1.21**	**1.225**	**1.24**	**1.27**
4	53	56	59	61	64	67	70	72	75	77	78	81
5	142	148	153	159	165	170	176	181	187	190	193	198
6	271	281	290	300	310	319	329	339	348	353	358	368
7	451	466	482	497	512	528	543	558	574	581	589	604
8	691	713	736	759	782	805	828	851	874	885	897	920
9	984	1016	1048	1080	1113	1145	1177	1209	1242	1258	1274	1306
10	1286	1328	1370	1412	1453	1495	1537	1578	1620	1641	1662	1703
11	1575	1625	1676	1726	1777	1827	1878	1928	1979	2004	2029	2080
12	1852	1911	1970	2029	2088	2147	2206	2265	2324	2353	2382	2439
13	2119	2186	2253	2320	2387	2453	2518	2581	2642	2671	2699	2749
14	2376	2451	2524	2595	2662	2724	2781	2829	2871	2888	2904	2928
15	2624	2697	2763	2820	2867	2905	2934	2955	2970	2976	2981	2987
16	2828	2879	2917	2946	2965	2978	2987	2992	2995	2997	2997	2998
17	2944	2966	2980	2989	2994	2996	2998	2999	2999	3000	3000	3000
18	2987	2993	2996	2998	2999	3000	3000	3000	3000	3000	3000	3000
19	2998	2999	2999	3000	3000	3000	3000	3000	3000	3000	3000	3000
20	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
21	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
22	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
23	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
24	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
25	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000

Figure 12-3: Power Curve, Mode 2

12.2.4 Power Curve, Mode 3

V90 - 3.0 MW, 50 Hz, Mode 3 - 104.4 dB(A)												
	Air Density [kg/m^3]											
Wind Speed [m/s]	**0.97**	**1**	**1.03**	**1.06**	**1.09**	**1.12**	**1.15**	**1.18**	**1.21**	**1.225**	**1.24**	**1.27**
4	53	56	58	61	64	67	70	72	75	77	78	81
5	142	148	153	159	165	170	176	181	187	190	193	198
6	271	281	290	300	310	319	329	339	348	353	358	368
7	451	466	481	497	512	527	543	558	573	581	588	604
8	680	703	725	748	770	793	815	838	860	872	883	906
9	920	950	980	1011	1041	1071	1101	1131	1162	1177	1192	1222
10	1149	1186	1224	1261	1298	1335	1373	1410	1447	1466	1484	1522
11	1361	1405	1449	1493	1536	1580	1624	1667	1711	1733	1755	1798
12	1493	1541	1588	1636	1684	1732	1780	1827	1875	1899	1923	1971
13	1575	1625	1676	1726	1776	1826	1876	1926	1976	2001	2026	2075
14	1818	1873	1927	1980	2033	2084	2135	2185	2234	2259	2283	2330
15	2265	2314	2361	2404	2446	2485	2522	2558	2590	2607	2623	2653
16	2697	2724	2749	2770	2790	2807	2823	2838	2851	2858	2864	2875
17	2918	2927	2935	2941	2947	2952	2956	2960	2963	2964	2966	2968
18	2984	2986	2988	2989	2990	2991	2992	2993	2993	2993	2994	2994
19	2998	2998	2998	2998	2999	2999	2999	2999	2999	2999	2999	2999
20	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
21	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
22	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
23	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
24	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
25	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000

Figure 12-4: Power Curve, Mode 3

12.2.5 Power Curve, Mode 4

V90 - 3.0 MW, 50 Hz, Mode 4 - 102.8 dB(A)												
	Air Density [kg/m^3]											
Wind Speed [m/s]	**0.97**	**1**	**1.03**	**1.06**	**1.09**	**1.12**	**1.15**	**1.18**	**1.21**	**1.225**	**1.24**	**1.27**
4	53	56	58	61	64	67	70	72	75	77	78	81
5	142	148	153	159	165	170	176	181	187	190	193	198
6	271	281	290	300	310	319	329	339	348	353	358	368
7	449	464	479	495	510	525	540	555	571	578	586	601
8	656	677	699	721	742	764	786	807	829	840	851	873
9	856	884	912	940	968	996	1024	1052	1080	1094	1108	1137
10	1047	1081	1115	1149	1183	1217	1251	1285	1319	1336	1353	1387
11	1231	1271	1311	1350	1390	1430	1469	1509	1549	1568	1588	1628
12	1391	1436	1480	1525	1569	1614	1658	1703	1748	1770	1792	1837
13	1503	1551	1599	1647	1695	1743	1791	1839	1887	1911	1935	1983
14	1544	1593	1642	1691	1740	1789	1838	1886	1935	1960	1984	2033
15	1647	1695	1742	1789	1835	1881	1926	1971	2016	2038	2061	2104
16	2064	2104	2141	2179	2213	2248	2281	2313	2345	2361	2376	2406
17	2579	2601	2621	2641	2658	2675	2691	2706	2721	2728	2736	2748
18	2874	2882	2889	2896	2901	2907	2912	2916	2921	2923	2925	2929
19	2973	2975	2976	2978	2979	2980	2982	2983	2984	2984	2984	2985
20	2995	2996	2996	2996	2997	2997	2997	2997	2997	2997	2997	2998
21	2999	2999	2999	2999	3000	3000	3000	3000	3000	3000	3000	3000
22	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
23	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
24	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
25	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000

Figure 12-5: Power Curve, Mode 4

12.3 Noise Levels

12.3.1 Noise curve V90 - 3.0 MW, 50 Hz, mode 0 - 109.4 dB (A)

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 ± 2^{o} Air density: 1.225 kg/m^{3}	
Hub Height	80m	105m
L_{wA} @ 4 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	97.0 5.6	98.2 5.8
L_{wA} @ 5 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	102 7.0	103.0 7.3
L_{wA} @ 6 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	105.8 8.4	106.5 8.7
L_{wA} @ 7 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	108.2 9.8	108.6 10.2
L_{wA} @ 8 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	109.3 11.2	109.4 11.7
L_{wA} @ 9 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	109.4 12.6	109.0 13.1
L_{wA} @ 10 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	106.7 14.0	106.3 14.6
L_{wA} @ 11 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	105.9 15.3	105.8 16.0
L_{wA} @ 12 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	105.7 16.7	105.7 17.5
L_{wA} @ 13 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	105.7 18.1	105.7 18.9

Figure 12-4: Noise Curve, Mode 0

12.3.2 Noise Curve V90 - 3.0 MW, 50 Hz, mode 1 - 107.8 dB (A)

Sound Power Level at Hub Height: Noise mode 1		
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 ± 2^o Air density: 1.225 kg/m^3	
Hub Height	80m	105m
L_{wA} @ 4 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	97.0 5.6	98.2 5.8
L_{wA} @ 5 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	102 7.0	103.0 7.3
L_{wA} @ 6 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	105.8 8.4	106.5 8.7
L_{wA} @ 7 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	107.7 9.8	107.8 10.2
L_{wA} @ 8 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	107.8 11.2	107.8 11.7
L_{wA} @ 9 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	107.8 12.6	107.7 13.1
L_{wA} @ 10 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	106.7 14.0	106.3 14.6
L_{wA} @ 11 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	105.9 15.3	105.8 16.0
L_{wA} @ 12 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	105.7 16.7	105.7 17.5
L_{wA} @ 13 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	105.7 18.1	105.7 18.9

Figure 12-5: Noise Curve, Mode 1

12.3.3 Noise Curve V90 - 3.0 MW, 50 Hz, mode 2 - 106.8 dB (A)

Sound Power Level at Hub Height: Noise mode 2		
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 ± 2^{o} Air density: 1.225 kg/m^{3}	
Hub Height	80m	105m
L_{wA} @ 4 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	97.0 5.6	98.2 5.8
L_{wA} @ 5 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	102 7.0	103.0 7.3
L_{wA} @ 6 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	105.6 8.4	106.3 8.7
L_{wA} @ 7 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	106.8 9.8	106.8 10.2
L_{wA} @ 8 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	106.8 11.2	106.8 11.7
L_{wA} @ 9 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	106.8 12.6	106.8 13.1
L_{wA} @ 10 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	106.8 14.0	106.3 14.6
L_{wA} @ 11 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	105.9 15.3	105.8 16.0
L_{wA} @ 12 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	105.7 16.7	105.7 17.5
L_{wA} @ 13 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	105.7 18.1	105.7 18.9

Figure 12-6: Noise Curve, Mode 2

12.3.4 Noise Curve V90 - 3.0 MW, 50 Hz, mode 3 - 104.4 dB (A)

Sound Power Level at Hub Height: Noise mode 3		
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 ± 2° Air density: 1.225 kg/m³	
Hub Height	80m	105m
L_{wA} @ 4 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	97.0 5.6	98.2 5.8
L_{wA} @ 5 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	102.0 7.0	102.9 7.3
L_{wA} @ 6 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	104.4 8.4	104.4 8.7
L_{wA} @ 7 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	104.4 9.8	104.4 10.2
L_{wA} @ 8 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	104.4 11.2	104.4 11.7
L_{wA} @ 9 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	104.4 12.6	104.4 13.1
L_{wA} @ 10 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	104.4 14.0	104.4 14.6
L_{wA} @ 11 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	104.9 15.3	105.8 16.0
L_{wA} @ 12 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	105.7 16.7	105.7 17.5
L_{wA} @ 13 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	105.7 18.1	105.7 18.9

Figure 12-7: Noise Curve, Mode 3

12.3.5 Noise Curve V90 - 3.0 MW, 50 Hz, mode 4 - 102.8 dB (A)

Sound Power Level at Hub Height: Noise mode 4		
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 ± 2° Air density: 1.225 kg/m³	
Hub Height	80m	105m
L_{wA} @ 4 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	97.0 5.6	98.2 5.8
L_{wA} @ 5 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	102.0 7.0	102.4 7.3
L_{wA} @ 6 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	102.8 8.4	102.8 8.7
L_{wA} @ 7 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	102.8 9.8	102.8 10.2
L_{wA} @ 8 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	102.8 11.2	102.8 11.7
L_{wA} @ 9 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	102.8 12.6	102.8 13.1
L_{wA} @ 10 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	102.8 14.0	102.8 14.6
L_{wA} @ 11 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	102.8 15.3	103.6 16.0
L_{wA} @ 12 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	105.0 16.7	105.7 17.5
L_{wA} @ 13 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	105.7 18.1	105.7 18.9

Figure 12-8: Noise Curve, Mode 4

Transport Guidelines
V90-3.0MW
Practical Information on Transport
For guidance only

Item no. 950049.R0 - Class I

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1. Preface

Please note that the following pages do not contain details on the measurements and weight of individual turbine components. This information can be found in the General Specifications for the turbine type in question.

As for details on turbine installation procedures please contact our Service Department.

Sea Transport

According to the Vestas Group Insurance policy we hereinafter refer to the following:

The marine transit rates agreed for this insurance apply only to cargoes and/or interests carried by mechanically self-propelled vessels of steel construction, classed by classification societies (to be informed upon request). Provided such vessels are:

a) (i) not bulk and/or combination carriers over 10 years of age.
(ii) not mineral oil tankers exceeding 50,000 GRT which are over 10 years of age.

b) (i) not over 15 years of age, OR
(ii) over 15 years of age but not over 25 years of age and have established and maintained a regular pattern of trading on an advertised schedule to load and unload at specified ports.

2. Road Structure

The road structure fully depends on the contours of the land whether based on crowned roads or side sloped design.

2.1 Drainage

Water should always be drained from the road and can never be allowed to stay on the road.

It should be drained either to the surrounding fields or be led to a drainage point beside the road. In order to do so, it is necessary to plan for this already at the base level.

2.2 Material

Base material must be interlocking rock/stone NOT containing clay but sand/gravel or other non-water binding material.

The finish material must be compatible non-slippery gravel.

2.3 Load capacity

The thickness of the base depends on the underlying soil – a soil analysis may be necessary.

The thickness of the finishing material should be min. 30 cm to ensure that there is enough material for grading the road afterwards to avoid bringing up heavy material from the base material.

Load capacity per axle should never be less than 15 ton/metric per axle.

3. Delivery Requirements

Parameter	Units	Value
Delivery	******	******
Access Road Minimum Width (Straight roads)	m	5.0
Access Road Minimum Bend Radius	See drawings pages 14 to 16	
Access Road Maximum Longitudinal Slope *)	degrees	8°
Access Road Maximum Lateral Slope	degrees	0-2°
Access Road Minimum Specification (Axle Load)	-	15 t
Erection – See Erection Manual	******	******

*) Based on drained roads consisting of crushed rock or similar with top layer of non-slippery gravel.

Gradients in excess of 8° (1:7, 14%) are subject to acceptance by haulier and Crane Hire Company

4. Transport

4.1 At Sea

The transport will typically consist of the following:

Quantity	Description
1	Complete Nacelle
2	160 ft Container containing 2 and 1 Blade(s)
4	Tower Sections
1	40 ft Container loaded with Cables/Controllers etc. (within legal limits)
1	40 ft container loaded with Tools and Generator for Erection

4.2 On Land by Truck

The transport will typically consist of the following:

Quantity	Description
1	Float loaded with complete Nacelle
1	Extendible Trailer for Blade Transport
4	Trailers for Towers
1	Trailer loaded with Cables/Controllers
1	Trailer loaded with 40 ft Container with Tools and Generator for Erection

The above is for guidance only

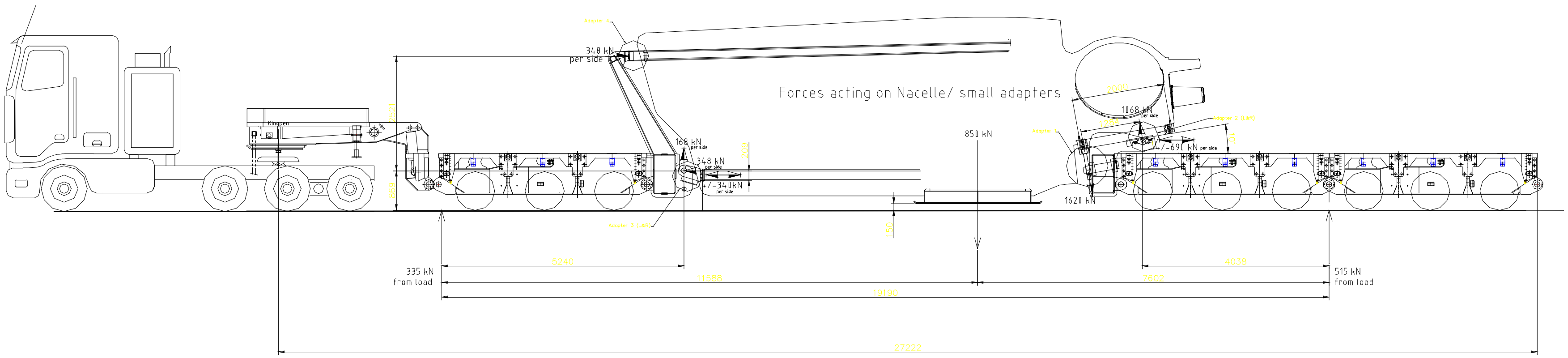
5. Required Equipment

NACELLE	
Float including Tractor	50.000 kg
Nacelle	83.000 kg
Adapter Ring for Bottom Frame	500 kg
Lifting Yoke	1.500 kg
Total Dimensions for Trailer Combination	33,3 x 3.40 x 4.35 m
BLADES	
Trailer and Tractor + 1 set (3 pcs.) blades	70.000 kg
Total Dimensions for Trailer Combination	47,00 x 3,50 x 4,10 m

TOWER SECTIONS (80 m tower)				
Section nr.	**Length**	**Max. Diameter**	**Min. Diameter**	**Weight**
Section 1	13350mm	4190mm	3807mm	52.000kg
Section 2	20355mm	3807mm	3284mm	47.500kg
Section 3	20460mm	3284mm	2773mm	32.800kg
Section 4	23285mm	2773mm	2316mm	29.500kg

6. Truck Load Nacelle

V90 Nacelle on road
Total vehicle weight consisting of complete nacelle approx. 130000 kg



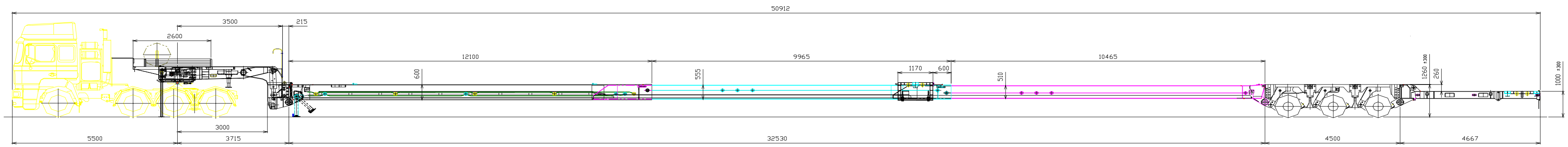
7. Trailer Transport V90 Nacelle

Nacelle on Tractor Trailer Combination

Nacelle lifted onto ship

8. Blade Transport Trailer

V90
Extendible Blade Transport Trailer



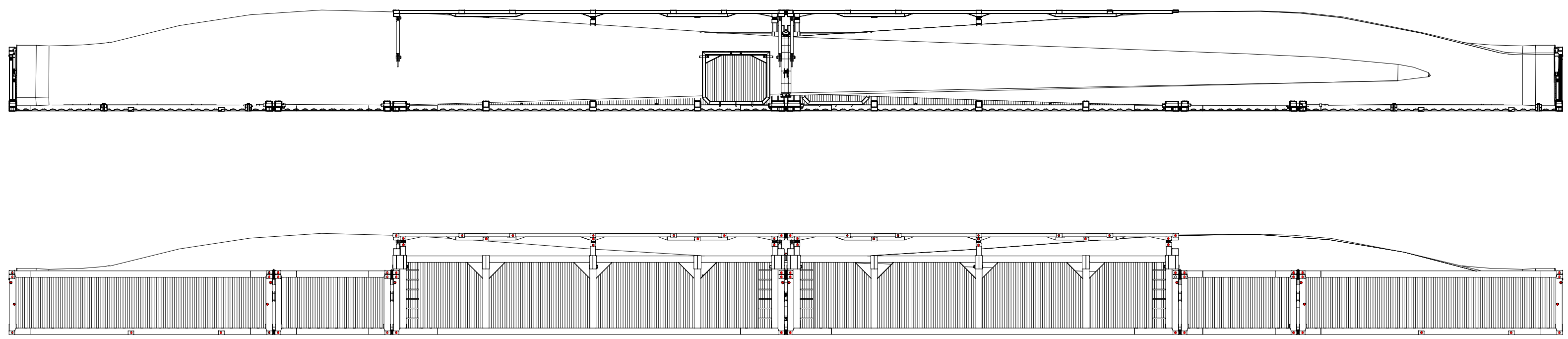
9. Truck Loaded with Blades

V90
TRANSPORT TRAILER FOR BLADES

10. Blade Container, Sea Transport

V90 160 ft CFC CONTAINER FOR TRANSPORT OF BLADES

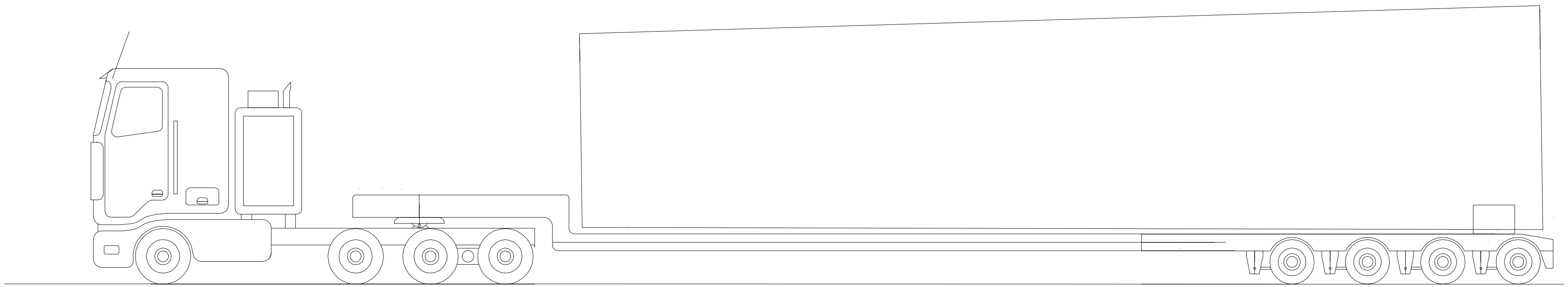
Total weight of the loaded container is approx. 40000 kg
Container dimensions: 48.364 x 3.150 x 2.438



Container lifted with a reach-stacker

Container loading

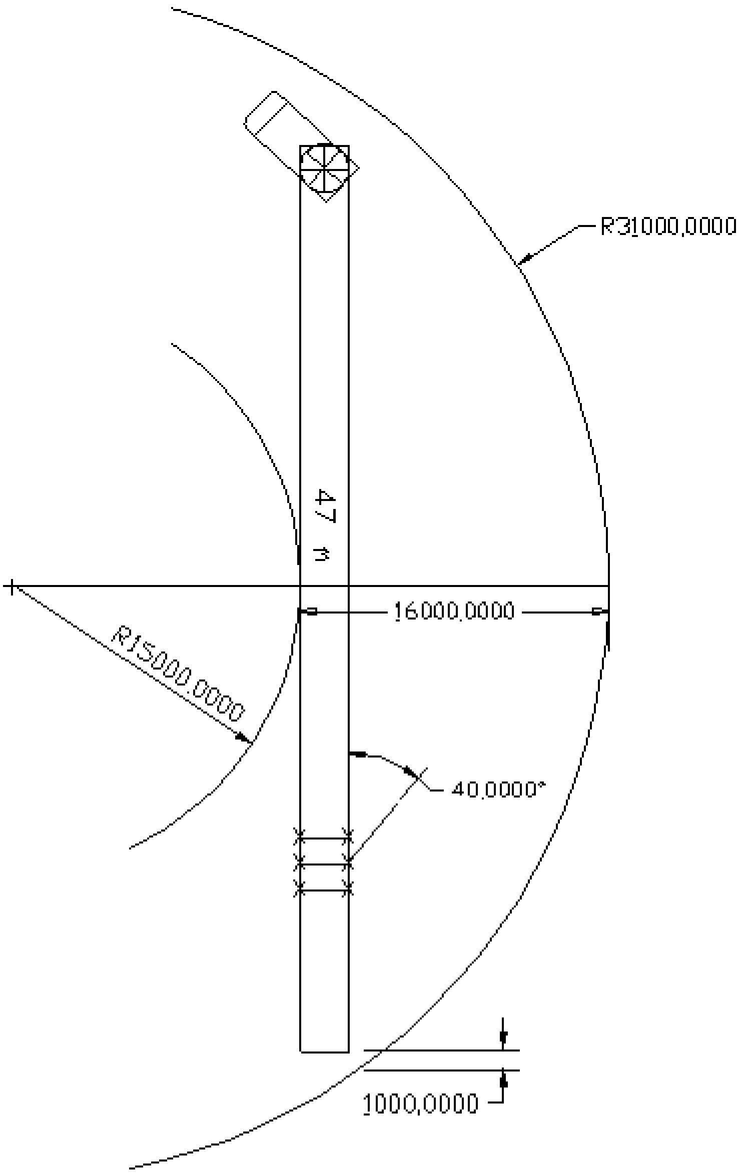
11. Transport of Tower Section



12. Road Transport V90 Blades

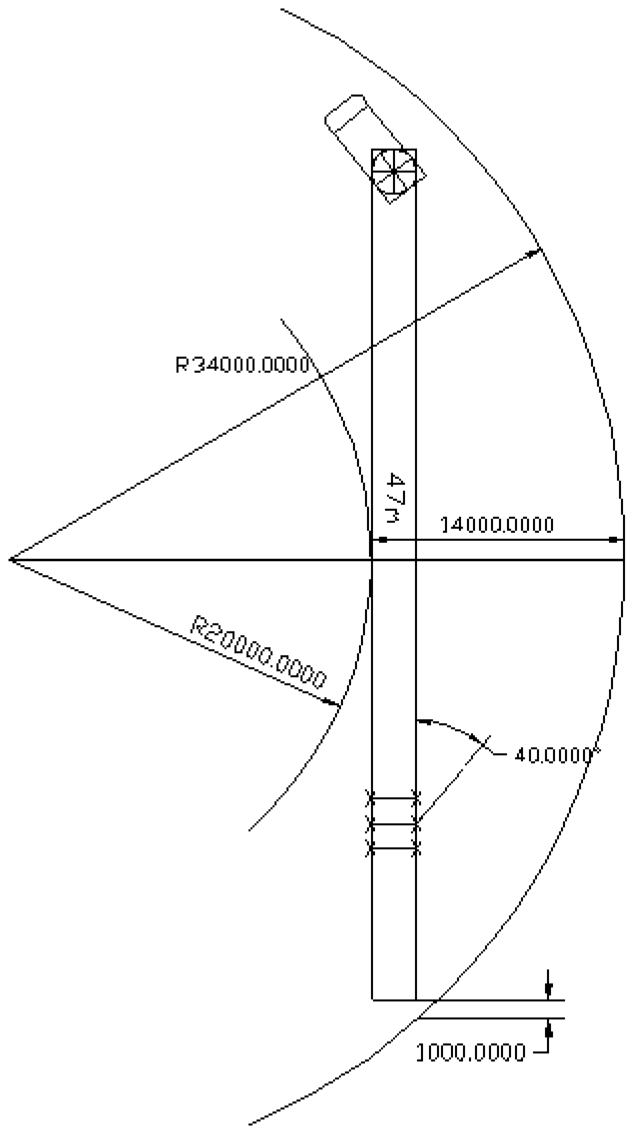
12.1 Road Radius 15 m

Radius required for a 47 m extendible trailer with electric/hydraulic manually controlled turnable wheels.



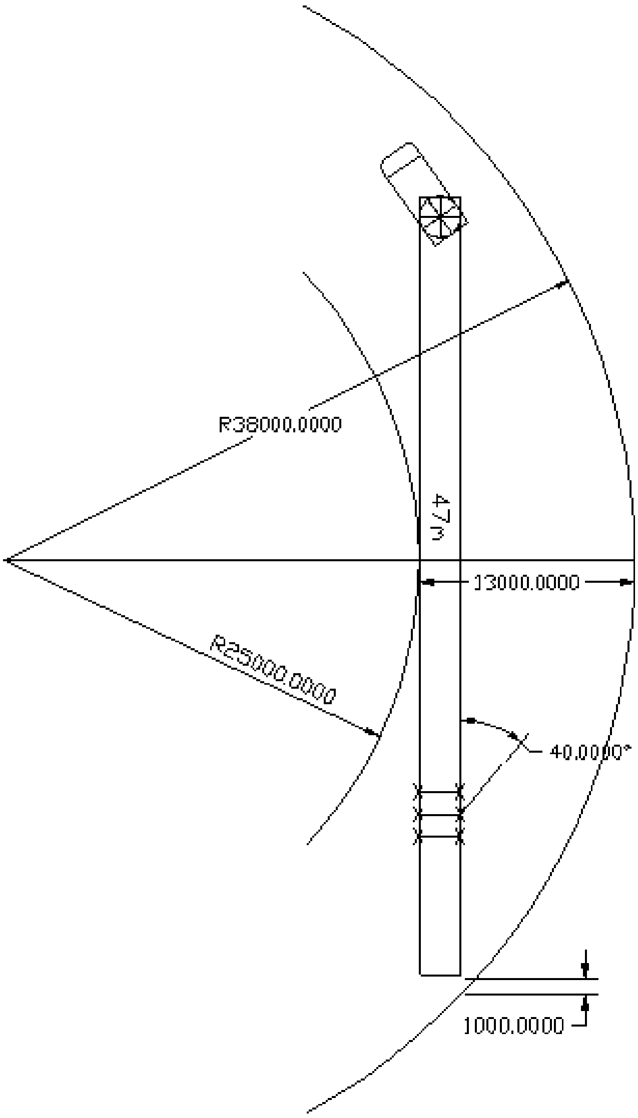
12.2 Road Radius 20 m

Radius required for a 47 m extendible trailer with electric/hydraulic manually controlled turnable wheels.



12.3 Road Radius 25 m

Radius required for a 47 m extendible trailer with electric/hydraulic manually controlled turnable wheels.



INDEPENDENT POWERSYSTEMS

Volume 4 – Appendix 2

Evolution Process

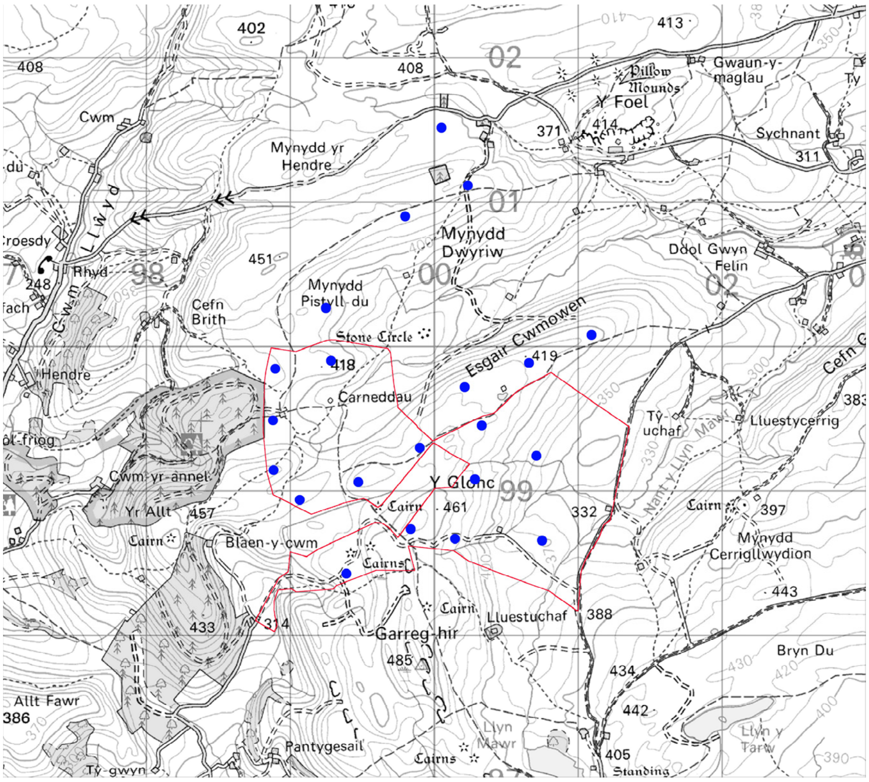


Figure 1: Initial Wind Farm layout with 21 wind turbines.

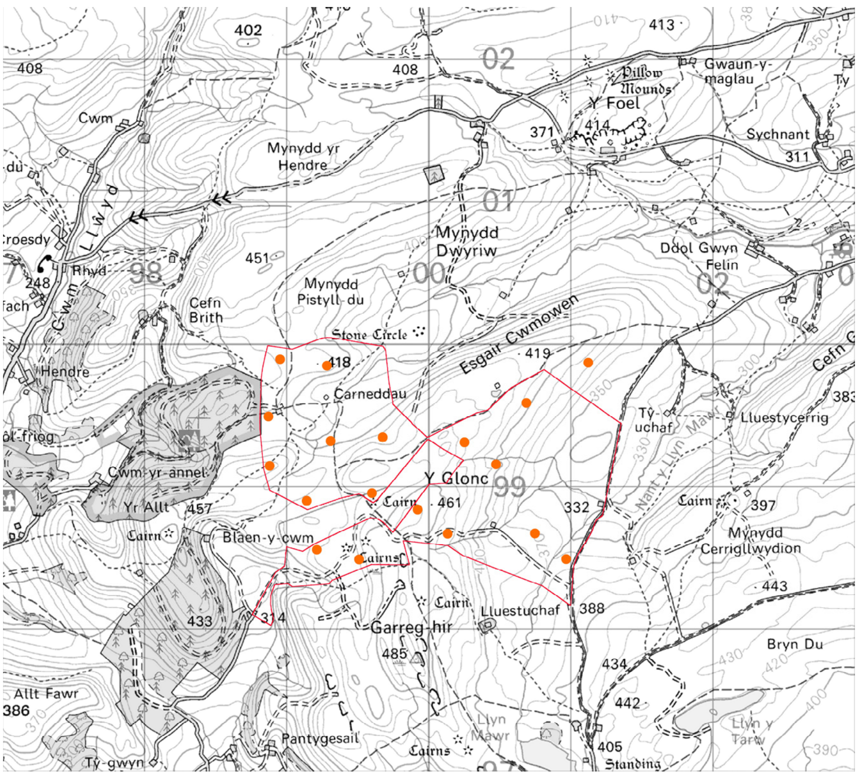


Figure 2: Intermediate Wind Farm layout with 18 turbines.