Supplemental Appendix E

Wind Energy Turbine Manufacturer Information

GE Renewable Energy

GE's 2MW Platform

A CUSTOMIZABLE PLATFORM TO ENHANCE SITING EFFICIENCY

Since entering the wind industry in 2002, GE Renewable Energy has invested more than $2 billion in next-generation wind turbine technology to provide more value to customers—whether at the turbine, plant or grid level. Through the use of advanced analytics, GE Renewable Energy is redefining the future of wind power, delivering with proven performance, availability and reliability. With the integration of big data and the industrial internet, we can help customers manage the variability that comes with this resource for smooth, predictable power. Our onshore product portfolio includes wind turbines with rated capacities from 1.6-3.4 MW and flexible support services that range from basic operations and maintenance to farm- or fleet-level enhancements.

For more information visit our website: www.ge.com/wind

2.0-2.4 MW Platform

GE's 2.2-2.4MW, 107m rotor wind turbine is an advanced evolution of the 1.x series, providing an up to 35% increase in Annual Energy Production (AEP) over its predecessor, the 1.85-87 (at a 2.4 rating). Configured for medium wind speeds, the 2.2-2.4MW turbine provides a 51% increase in swept area with the 107-meter rotor, and an extra 350-450 kW output at rated wind speed compared to the 1.85-87 turbine, improving project economics for wind developers. GE's proprietary Advanced Loads Control combines drivetrain sensors with Mark* VIe turbine controller capabilities to individually pitch the blades and improve load handling performance.

GE's 2.0-2.3MW, 116-meter rotor wind turbine offers a 27% increase in swept area when compared to the 1.7-103 turbine, resulting in an up to 26% increase in Annual Energy Production (AEP) at 7.5 m/s (at a 2.3 rating). This increase in blade swept area allows greater energy capture and improved project economics for wind developers[†]. GE's 2.0-116 turbine has a 53.3% gross capacity factor at 7.5 m/s, a class leading performance. GE's proprietary 56.9-meter blade is specifically for the 2.0-2.3MW rating of this platform, enabling longer length, lower loads and improved performance.

GE's stringent procedures result in a turbine engineered for high performance and availability. The use of selected components from both the 1.x and 2.x platforms ensures the consistent workhorse performance and reliability that GE wind turbines are known for. The 2.0-2.4MW platform utilizes the same drivetrain and electrical system architecture as GE's 1.x series, with both systems scaled and upgraded to provide improved performance along with greater wind turbine energy production. Other critical components have been scaled from the existing platforms to meet the specific technical requirements of this evolutionary turbine.

Ensuring consistent performance, reliability and efficiency, GE's new 2.0-2.4MW platform of wind turbines is an advanced evolution of the 1.x platform series, scaling and developing 1.x platform electrical system upgrades to increase the rating of the turbine from 1.7 MW to range from 2.0-2.4 MW, allowing higher energy production.

[†] Comparative statements refer to GE technology unless otherwise stated.

Building Upon the Proven 1.x and 2.x Platforms

The evolution of GE's 1.5 MW turbine began with the 1.5i turbine introduced in 1996. The 65-meter rotor diameter turbine soon was increased to 70.5-meters in the 1.5s, then to 77-meters in the 1.5sle turbine that was introduced in 2004. Building on the exceptional performance and reliability of the 1.5sle, GE introduced the 1.5xle with its 82.5-meter diameter in 2005. Subsequent improvements led to the introduction of the 1.6-82.5 turbine in 2008—followed by the 1.6-87 in 2011, and ultimately the 1.85-82.5 and 1.85-87 in 2013. Ongoing investment in the industry workhorse resulted in the introduction of GE's 1.6-100 and 1.7-100, wind turbines with a 100-meter rotor. This product evolution provides increased capacity factor while increasing AEP by 20–24% over the previous models. Built from the maturity of its predecessors, the 2.0-2.4MW platform evolution provides increased capacity factor while increasing AEP and application space of GE's 1-2MW platform of products.

Significant component enhancements to the 1.x models have resulted in a substantial performance increase, enabling the use of a 107-meter and 116-meter rotor on the 1.x series, and a nameplate range of 2.0-2.4MW (with applicable rotor). These enhancements include new aerodynamics enabling a greater blade length (116-meter rotor), larger bedplate, generator frame and gearbox, controls improvements, and enhanced power conversion capabilities resulting in an increase in nameplate and AEP. Made for high reliability, GE's 2.0-2.4MW platform can provide excellent availability, comparable with the 1.x series units operating in the field today.

Technical Description

GE's 2.0-2.4MW platform, is a three-blade, upwind, horizontal axis wind turbine with a rotor diameter of either 107 or 116 meters. The turbine rotor and nacelle are mounted on top of a tubular steel tower, providing a hub height of either 80 or 94 meters. The turbine uses active yaw control to keep the blades pointed into the wind. The 2.0-2.4MW platform operates at a variable speed and uses a doubly fed asynchronous generator with a partial power converter system.

Specifications:

- 2.2-2.4MW, 107-meter rotor wind turbine: engineered to IEC 61400-22 ed 3, Class IIS
- 2.0-2.3MW, 116-meter rotor wind turbine: engineered to IEC 61400-22 ed 3, Class IIIS
- Standard and cold weather extreme options
- Standard tower corrosion protection: C2 internal and C3 external with internal and external C4/C5 options available
- Rotational direction: Clockwise viewed from an upwind location
- Speed regulation: Electric drive pitch control with battery backup
- Aerodynamic brake: Full feathering of blade pitch

Features and Benefits

- 2.2-2.4MW, 107-meter rotor: higher AEP than its 1.x predecessors by incorporating a larger gearbox scaled from GE's 2.x platform and longer 52.2-meter blades
- 2.0-2.3MW, 116-meter rotor: GE proprietary 56.9-meter blade; highest capacity factor in its class
- Engineered to meet or exceed the 1.x platform's historic high availability
- Grid friendly options are available
  - Enhanced Reactive Power, Voltage Ride Thru, Power Factor Control
- Wind Farm Control System; WindSCADA*
- Available in both 50 Hz and 60 Hz versions for global suitability

Construction:

Towers: Tubular steel sections provide a hub height of either 80 or 94 meters

Blades: GE 52.2 meter blades (107-meter rotor), and GE 56.9m meter blades (116-meter rotor)

Drivetrain components: GE's 2.0-2.4MW platform uses an enhanced gearbox, main shaft, and generator with appropriate improvements to enable the 107-meter diameter rotor in medium winds, and the 116-meter rotor in lower wind speeds

Enhanced Controls Technology

The 2.0-2.4MW wind turbine products employ enhanced control features including:

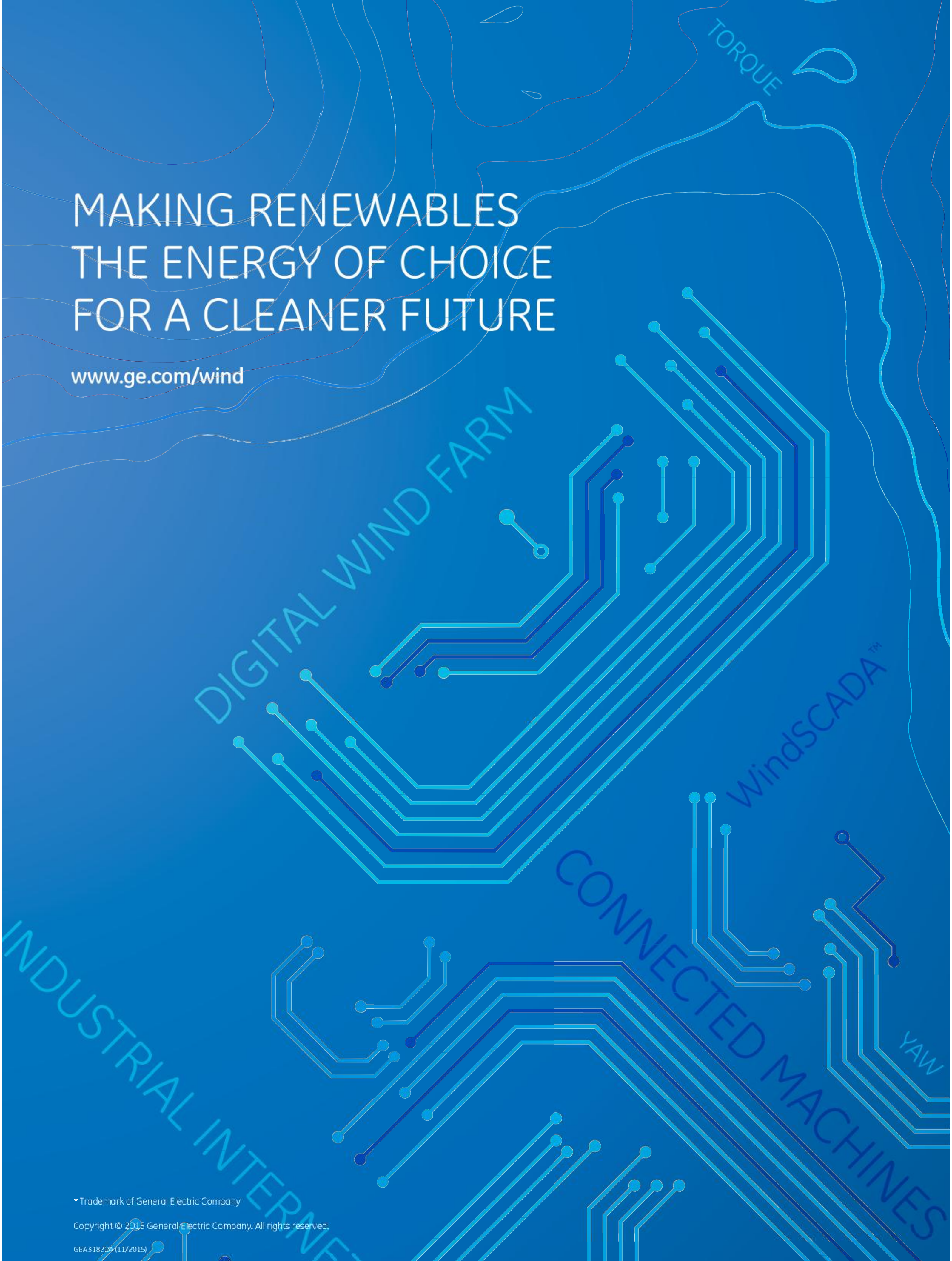
- GE's patented Advanced Loads Control reduces loads on turbine components by measuring stresses and individually adjusting blade pitch.
- Controls developed by GE Global Research to reduce extreme loads, including those near rated wind speeds, to improve Annual Energy Production (AEP).

Condition Monitoring System (option)

GE's Condition Monitoring System* (CMS) and SCADA Anomaly Detection Services, a complementary suite of advanced condition monitoring solutions, proactively detect impending drivetrain and whole-turbine issues enabling increased availability and decreased maintenance expenses. Built upon half a century of power generation drivetrain and data anomaly monitoring experience, this service solution is now a standard feature available on GE's 2.0-2.4MW platform, for both rotor types.

MAKING RENEWABLES THE ENERGY OF CHOICE FOR A CLEANER FUTURE

www.ge.com/wind



GEA31820A (11/2015)

GE Power & Water

– Original –

Technical Documentation
Wind Turbine Generator Systems
1&2MW Platform

Technical Description and Data

Applicable for Wind Turbine Generators from 2.0 MW to 2.4 MW

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All technical data is subject to change in line with ongoing technical development!

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Table of Contents

1 Introduction

This document summarizes the technical description and specifications of the GE Energy (GE) 1&2MW Platform wind turbine generator systems (applicable for systems from 2.0 MW to 2.4 MW).

2 Technical Description of the Wind Turbine and Major Components

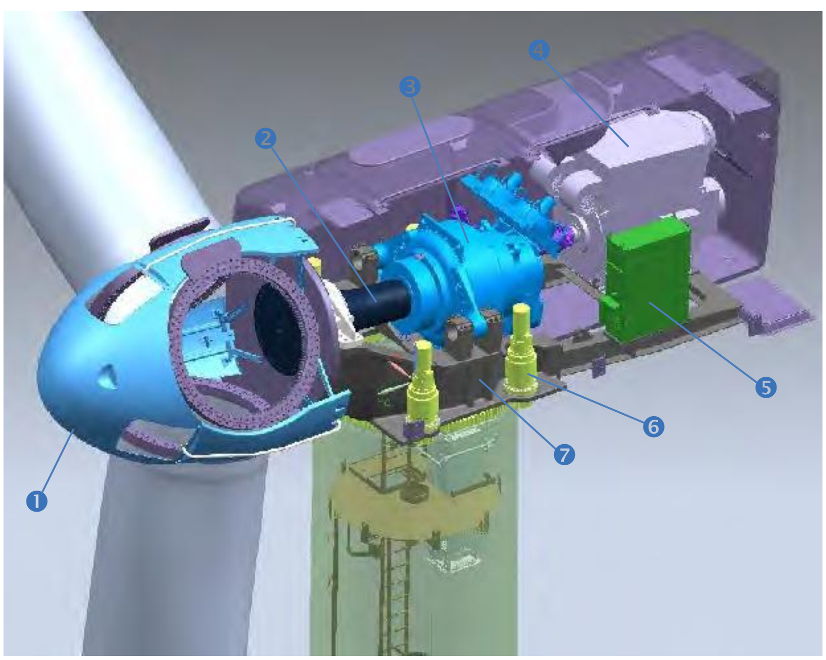
The wind turbine is a three bladed, upwind, horizontal-axis wind turbine with a rotor diameter of 107 or 116m. The turbine rotor and nacelle are mounted on top of a tubular tower with the following hub heights:

	2.2 to 2.4MW,-107m rotor	2.0 to 2.3MW,-116m rotor
50 Hz	80/94 m	80/94 m
60 Hz	80/94 m	80/94 m

Table 1: 1&2MW Platform hub heights for 50/60Hz markets, from 2.0-2.4 MW

The Wind Turbine Generator (WTG) employs active yaw control (designed to steer the machine with respect to the wind direction), active blade pitch control (designed to regulate turbine rotor speed), and a generator/power electronic converter system.

The wind turbine generator features a distributed drive train design consisting of a main shaft bearing, gearbox, and generator. Figure 1 shows these, as well as other major components such as the bedplate, yaw drives and an electrical panel box.



1 – Hub
2 – Main shaft
3 - Gearbox
4 - Generator
5 – Electrical panel box
6 – Yaw drive
7 - Bedplate

Figure 1: GE Energy 1&2MW Platform wind turbine nacelle layout, for generator systems of 2.0-2.4 MW

2.1 Rotor

Two rotor diameter WTGs are offered. The 107 m rotor diameter has a swept area of 8,992 m^2, the 116 m rotor diameter has a swept area of 10,568 m^2. The 107 m rotor is designed to operate between 8.27 and 15.9 rpm, while the 116 rotor is designed to operate between 7.67 and 15.68 rpm. Rotor speed is regulated by a combination of blade pitch angle adjustment and generator/converter torque control. The rotor spins in a clock-wise direction under normal operating conditions when viewed from an upwind location.

Full blade pitch angle range is approximately 90°, with the 0° position being with the airfoil chord line flat to the prevailing wind. The blades being pitched to a full feather pitch angle of approximately 90° accomplishes aerodynamic braking of the rotor; whereby the blades "spill" the wind thus limiting rotor speed.

2.2 Blades

There are three rotor blades for each wind turbine generator. The airfoils transition along the blade span with the thicker airfoils being located in-board towards the blade root (hub) and gradually tapering to thinner cross sections out towards the blade tip.

Vortex Generators (VGs) are attached to the suction side of the blades to increase turbine performance. These are molded plastic vanes that create vortices, attached to the blades in rows in the inner 1/3 of the blades. VGs increase the amount of attached flow over the blade and increase its efficiency.

Low Noise Trailing Edge (LNTE) are an optional feature for sites requiring reduced noise capability.

2.3 Blade Pitch Control System

The rotor utilizes three (one for each blade) independent electric pitch motors and controllers to provide adjustment of the blade pitch angle during operation. Blade pitch angle is adjusted by an electric drive that is mounted inside the rotor hub and is coupled to a ring gear mounted to the inner race of the blade pitch bearing (see Figure 1).

GE's active-pitch controller enables the wind turbine generator rotor to regulate speed, when above rated wind speed, by allowing the blade to "spill" excess aerodynamic lift. Energy from wind gusts below rated wind speed is captured by allowing the rotor to speed up, transforming this gust energy into kinetic energy which may then be extracted from the rotor.

Three independent back-up units are provided to power each individual blade pitch system to feather the blades and shut down the machine in the event of a grid line outage or other fault. By having all three blades outfitted with independent pitch systems, redundancy of individual blade aerodynamic braking capability is provided.

2.4 Hub

The hub is used to connect the three rotor blades to the wind turbine generator main shaft. The hub also houses the three electric blade pitch systems and is mounted directly to the main shaft. Access to the inside of the hub is provided through a hatch.

2.5 Gearbox

The gearbox in the wind turbine generator is designed to transmit power between the low-rpm turbine rotor and high- rpm electric generator. The gearbox is a multi-stage planetary/helical gear design. The gearbox is mounted to the machine bedplate. The gearing is designed to transfer torsional power from the wind turbine rotor to the electric generator. A parking brake is mounted on the high-speed shaft of the gearbox.

2.6 Bearings

The blade pitch bearing is designed to allow the blade to pitch about a span-wise pitch axis. The inner race of the blade pitch bearing is outfitted with a blade drive gear that enables the blade to be driven in pitch by an electric gear-driven motor/controller.

The main shaft bearing is a roller bearing mounted in a bearing cap arrangement.

The bearings used inside the gearbox are of the cylindrical and tapered roller type. These bearings are designed to provide bearing and alignment of the internal gearing shafts and accommodate radial and axial loads.

2.7 Brake System

The electrically actuated individual blade pitch systems act as the main braking system for the wind turbine generator. Braking under normal operating conditions is accomplished by feathering the blades out of the wind. Any single feathered rotor blade is designed to slow the rotor, and each rotor blade has its own back-up to provide power to the electric drive in the event of a grid line loss.

The wind turbine generator is also equipped with a mechanical brake located at the output (high-speed) shaft of the gearbox. This brake is only applied as an auxiliary brake to the main aerodynamic brake and to prevent rotation of the machinery as required by certain service activities.

2.8 Generator

The generator is a doubly-fed induction type. The generator meets protection class requirements of the International Standard IP 34 (duct ventilated). The generator is mounted to the generator frame and the mounting is designed so as to reduce vibration and noise transfer to the bedplate.

2.9 Flexible Coupling

Designed to protect the drive train from excessive torque loads, a flexible coupling is provided between the generator and gearbox output shaft. This coupling is equipped with a torque-limiting device sized to keep the maximum allowable torque below the maximum design limit of the drive train.

2.10 Yaw System

A ball bearing attached between the nacelle and tower facilitates yaw motion. Planetary yaw drives (with brakes that engage when the drive is disabled) mesh with the outside gear of the yaw bearing and steer the machine to track the wind in yaw. The passive yaw brakes prevent the yaw drives from experiencing peak loads from turbulent wind.

The controller activates the yaw drives to align the nacelle to the average wind direction based on the wind vane sensor mounted on top of the nacelle.

A cable twist sensor provides a record of nacelle yaw position and cable twisting. After the sensor detects excessive rotation in one direction, the controller automatically brings the rotor to a complete stop, untwists the cable by counter yawing of the nacelle, and restarts the wind turbine.

2.11 Tower

The wind turbine is mounted on top of a tubular tower. The tubular tower is manufactured in sections from steel plate. Access to the turbine is through a lockable steel door at the base of the tower. Service platforms are provided. Access to the nacelle is provided by a ladder and a fall arresting safety system is included. Interior lights are installed at critical points from the base of the tower to the tower top.

2.12 Nacelle

The nacelle houses the main components of the wind turbine generator. Access from the tower into the nacelle is through the bottom of the nacelle. The nacelle is ventilated. It is illuminated with electric light. A hatch at the front end of the nacelle provides access to the blades and hub. The rotor can be secured in place with a rotor lock.

2.13 Anemometer, Wind Vane and Lightning Rod

An anemometer, wind vane and lightning rod are mounted on top of the nacelle housing. Access to these sensors is accomplished through a hatch in the nacelle roof.

2.14 Lightning Protection

The rotor blades are equipped with lightning receptors mounted in the blade. The turbine is grounded and shielded to protect against lightning, however, lightning is an unpredictable force of nature, and it is possible that a lightning strike could damage various components notwithstanding the lightning protection deployed in the machine.

2.15 Wind Turbine Control System

The wind turbine machine can be controlled automatically or manually from either an interface located inside the nacelle or from a control box at the bottom of the tower. Control signals can also be sent from a remote computer via a Supervisory Control and Data Acquisition System (SCADA), with local lockout capability provided at the turbine controller.

Service switches at the tower top prevent service personnel at the bottom of the tower from operating certain systems of the turbine while service personnel are in the nacelle. To override any machine operation, Emergency-stop buttons located in the tower base and in the nacelle can be activated to stop the turbine in the event of an emergency.

2.16 Power Converter

The wind turbine uses a power converter system that consists of a converter on the rotor side, a DC intermediate circuit, and a power inverter on the grid side.

The converter system consists of a power module and the associated electrical equipment. Variable output frequency of the converter allows operation of the generator.

3 Technical Data

3.1 Rotor

Maximum power output	2.2 to 2.4MW, 107m rotor	2.0 to 2.3MW, 116m rotor
Maximum power output	2200 to 2400 kW	2000 to 2300 kW
Diameter	107 m	116 m
Number of blades	3	3
Swept area	8,992 m²	10,568 m²
Rotor speed range	8 to 16 rpm	8 to 15.7 rpm
Rotational direction	Clockwise looking downwind	Clockwise looking downwind
Tip speed @ rated power	80.1 m/s For all nameplate variants.	81.7 m/s to 85.4m/s.
Orientation	Upwind	Upwind
Speed regulation	Pitch control	Pitch control
Aerodynamic brakes	Full feathering	Full feathering

3.2 Pitch System

	2.2 to 2.4MW, 107m rotor	2.0 to 2.3MW,116m rotor
Principle	Independent blade pitch control	Independent blade pitch control
Actuation	Individual electric drive	Individual electric drive

3.3 Yaw System

	2.2 to 2.4MW, 107m rotor	2.0 to 2.3MW, 116m rotor
Yaw rate	0.5 degree/s	0.5 degree/s

3.4 Corrosion Protection

Atmospheric corrosion protection (corrosion categories as defined by ISO 12944-2:1998)				
50 & 60 Hz	Standard		Enhanced (Option)	
Recommended Climate	Dry, arid, inland, non-industrial areas		Humid, coastal, industrial areas	
Component	Internal	External	Internal	External
Blades	C-4	C-5	C-4	C-5
Tower shell coating	C-2	C-3	C-4	C-5M
Tower internal fasteners, tower stair fasteners	C-4	C-4	C-4	C-5
Hub, bedplate, generator frame, mainshaft, pillowblock, gearbox, generator	C-4	C-4	C-4	C-4
Nacelle, hub fasteners	C-4	C-4	C-4	C-5
Automatic lubrication system (option for 1&2MW)	C-3	C-3	C-5	C-5

4 Operational Limit

	2.2 to 2.4MW, 107m rotor	2.0 to 2.3MW, 116m rotor
Height above sea level	Maximum 3000 m. See notes in section maximum standard ambient temperature below.	Maximum 3000 m. See notes in section maximum standard ambient temperature below.
Minimum temperature (standard) operational/survival	Standard weather: -15°C / -20°C Cold weather package (60Hz only): -30 °C/ -40 °C Switching on takes place at a hysteresis of 5K (-10°C resp. -25°C)	Standard weather: -15°C / -20°C Cold weather package (60Hz only): -30 °C/ -40 °C Switching on takes place at a hysteresis of 5K (-10°C resp. -25°C)
Maximum standard ambient temperature (operation / survival)	+40°C / +50°C The turbine has a feature reducing the maximum output, resulting in minimized turbine revolutions once the component temperatures approach predefined thresholds. This feature operates best at higher altitudes, as the heat transfer properties of air diminish with decreasing density. Please note that the units are not de-rated in respect to site conditions. The units' reactions related to this feature are based solely on sensor temperatures.	+40°C / +50°C The turbine has a feature reducing the maximum output, resulting in minimized turbine revolutions once the component temperatures approach predefined thresholds. This feature operates best at higher altitudes, as the heat transfer properties of air diminish with decreasing density. Please note that the units are not de-rated in respect to site conditions. The units' reactions related to this feature are based solely on sensor temperatures.
Wind conditions according to IEC 61400	2.2-107: 50/60Hz (IECs) Vaverage = 8.5m/s TI=14% with Ed3 (16% Ed2) 2.3-107: 50/60Hz (IECs) Vavergae = 8.2m/s TI=14% with Ed3 (16% Ed2) 2.4-107: 50/60Hz (IECs) Vavergae = 8.2m/s TI=14% with Ed3 (16% Ed2)	2.0-116: 50/60Hz (IECs) Vaverage= 8.0m/s TI=13.5% with Ed3 (15%Ed2) 2.1-116: 50/60Hz (IECs) Vaverage= 8.0m/s TI=13.5% with Ed3 (15%Ed2) 2.2-116: 50/60Hz (IECs) Vaverage= 7.5m/s TI=13.5% with Ed3 (15%Ed2) 2.3-116: 50/60Hz (IECs) Vaverage = 7.5m/s TI=13.5% with Ed3 (15%Ed2)
Maximum extreme gust (10 min) according to IEC 61400	50 / 60 Hz: Standard weather package: 40 m/s Cold Weather Package : 40m/s	50 / 60 Hz: Standard weather package: 38 m/s Cold Weather Package: 38m/s

2 MW PLATFORM

Wind. It means the world to us.™

Are you looking for the maximum return on **your investment** in wind energy?

Wind energy means the world to us. And we want it to mean the world to our customers, too, by maximising your profits and strengthening the certainty of your investment in wind power.

That's why, together with our partners, we always strive to deliver cost-effective wind technologies, high quality products and first class services throughout the entire value chain. And it's why we put so much emphasis on the reliability, consistency and predictability of our technology.

These aren't idle words. We have over 30 years' experience in wind energy. During that time, we've delivered more than 70 GW of installed capacity and we currently monitor over 27,000 wind turbines across the globe. Tangible proof that Vestas is the right partner to help you realise the full potential of your wind site.

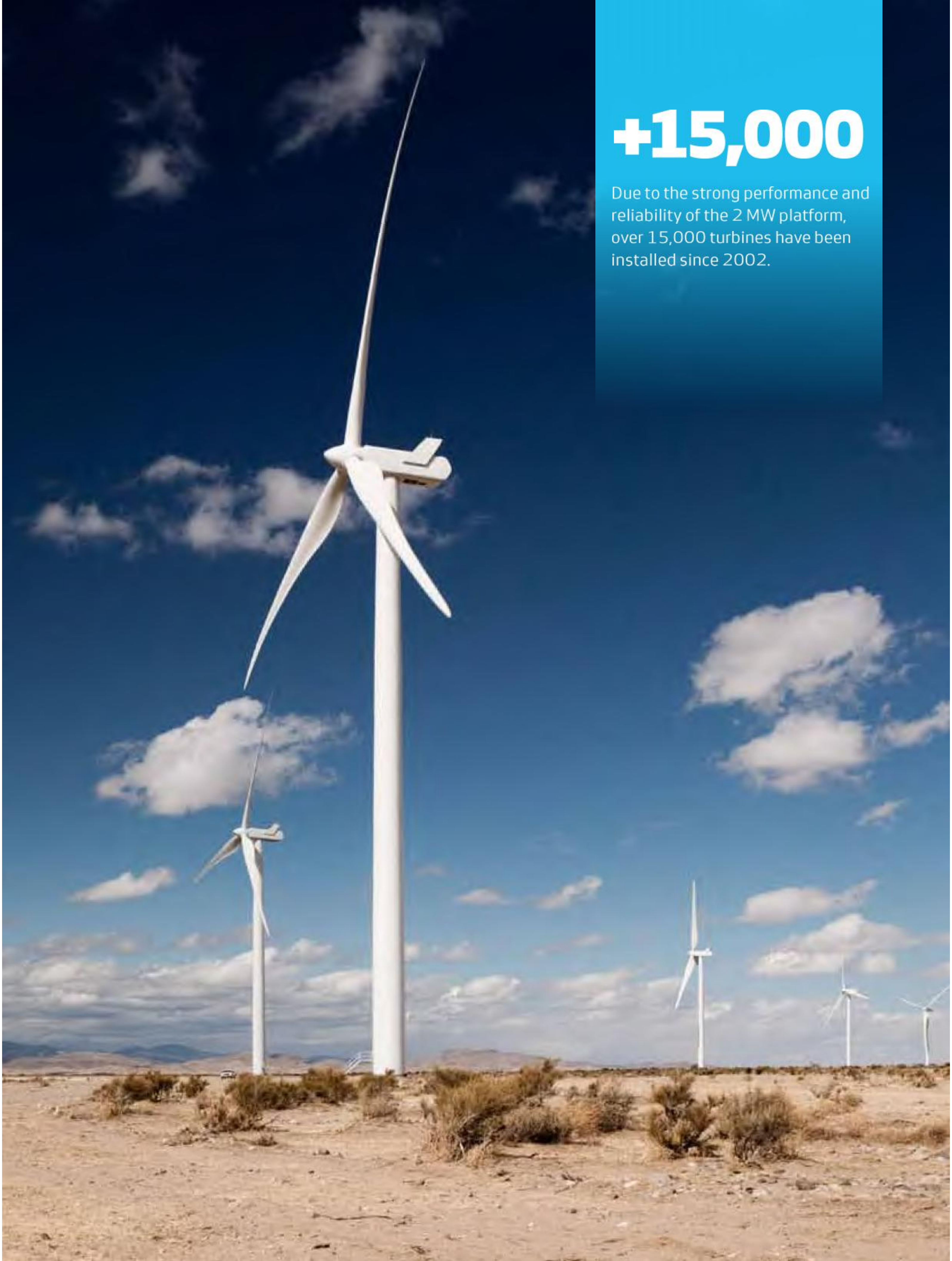
What is the 2 MW platform?

Our 2 MW platform provides industry-leading reliability, serviceability and availability. Durable and dependable, the platform is built on technology that has been proven in the field over more than a decade. The 2 MW platform reduces your costs, minimises the risk of turbine downtime and helps to safeguard your investment.

You can choose from four turbines on the 2 MW platform:

- V90-1.8/2.0 MW® IEC IIA/IEC IIIA
- V100-1.8/2.0 MW™ IEC IIIA/IEC S
- V100-2.0 MW® IEC IIB
- V110-2.0 MW™ IEC IIIA

Each 2 MW turbine incorporates enhancements that improve performance and reliability, reducing your cost of energy. The platform's predictability allows you to forecast confidently, strengthening the business case for investment, while the tried-and-tested design ensures you can produce energy on low, medium and high-wind onshore sites at the lowest possible cost, even in extreme weather conditions. In addition, remote monitoring and easy servicing keep operational costs at a minimum, while its highly-tested components and power and control systems enhance reliability.



+15,000

Due to the strong performance and reliability of the 2 MW platform, over 15,000 turbines have been installed since 2002.

How does the 2MW platform increase **reliability** and **performance?**

Created with future generations of turbines in mind, the 2 MW platform's single-piece bed frame and stronger main bearing housing provide a better foundation for loads. The toughened frame and housing – each made from single-piece castings – work in conjunction to absorb higher loads from the rotor.

Additionally, the housing ensures correct alignment during bearing assembly, making the process more accurate and efficient and distributing loads evenly. These improvements combine to increase production capabilities and reduce downtime.

A reliable performer

The 2 MW platform is an extremely reliable turbine, which is documented through its strong availability performance. With the newest addition of rotor size, the 2 MW platform offers a competitive selection of turbines for all wind segments.

Thoroughly tested

The current 2 MW platform is built on unique knowledge from more than a decade of operational experience. We constantly monitor the majority of the installed 2 MW turbines, providing us with very detailed and invaluable information about how the turbine operates under all kinds of site conditions.

Our quality-control system ensures that each component is produced to design specifications and performs to peak potential at site. We also employ a Six Sigma philosophy and have identified critical manufacturing processes (both in-house and for suppliers). We systematically monitor measurement trends that are critical to quality, locating defects before they occur.

Innovative CoolerTop®

Our exclusive CoolerTop® technology uses the wind's own energy to generate the cooling required, rather than consuming energy from the wind turbine generator. CoolerTop® has no moving parts and requires little maintenance. Furthermore, the absence of cooling fans contributes to turbine efficiency and makes no noise.

Load and Power Modes increase energy output

The 2 MW platform supports Load and Power Modes, used to maximise energy production under specific wind and site conditions. Based on a site analysis, turbines can be configured to run derated when wind conditions require it. Conversely, under mild wind conditions, the turbine can be uprated - maximising annual energy production.

The 2 MW platform covers a wide range of wind segments enabling you to find the best turbine for your specific site.

WINDCLASSES - IEC

TURBINE TYPE	IEC III (6.0 – 7.5 m/s)	IEC II (7.5 – 8.5 m/s)	IEC I (8.5 – 10.0 m/s)
2 MW TURBINES			
V90-1.8/2.0 MW® IEC IIA/ IEC IIIA	Standard IEC conditions	Standard IEC conditions	Site dependent
V100-1.8/2.0 MW™ IEC IIIA/IEC S	Standard IEC conditions		
V100-2.0 MW® IEC IIB		Standard IEC conditions	Site dependent
V110-2.0 MW™ IEC IIIA	Standard IEC conditions	Site dependent	

■ Standard IEC conditions ■ Site dependent

Low Balance of Plant, installation and transportation costs

At Vestas, we use technology tailored to control loads on specific tower heights. We have applied this principle to the 2 MW platform by reducing both the weight of the turbine and the loads on the tower and foundation. This reduces foundation costs, saving you unnecessary expense.

All 2MW turbines are easy to transport (by rail, truck or ship) to virtually any site around the world. In terms of weight, height and width, all components comply with local and international standard transportation limits, ensuring you incur no unforeseen costs. In addition, 2MW turbines are built and maintained using tools and equipment that are standard in the installation and servicing industries – minimising maintenance costs.

Vestas Online® Business

All Vestas wind turbines benefit from Vestas Online® Business, the latest Supervisory Control and Data Acquisition (SCADA) system for modern wind power plants. This flexible system includes an extensive range of monitoring and management functions to control your wind power plant in the same way as a conventional power plant. Vestas Online® Business enables you to optimise production levels, monitor performance, and produce detailed, tailored reports from anywhere in the world. The system's power plant controller provides active and reactive power regulation, power ramping and voltage control.

24/7 remote surveillance with VMP Global® and Vestas Online® Business

To reduce the cost of energy, the 2 MW platform is equipped with VMP Global®, our latest turbine control and operation software. Developed to run this latest generation of turbines, VMP Global®, combined with Vestas Online® Business, automatically manages the turbine 24/7 and ensures maximum power generation. The application also monitors and troubleshoots the turbines – both onsite and remotely – saving further expense on servicing.

Designed for serviceability

Service is facilitated by the overall design of the 2 MW platform and components are specifically positioned for easy access.

Options available for the 2 MW platform

- Condition Monitoring System
- Vestas Ice Detection
- Smoke Detection
- Shadow Detection
- Low Temperature Operation to -30°C
- Aviation Lights
- Aviation Markings on the Blades
- Obstacle Collision Avoidance System (OCAS™)

Would you **benefit** from uninterrupted control of wind energy production?

Knowledge about wind project planning is key
Getting your wind energy project up and operating as quickly as possible is fundamental to its long-term success. One of the first and most important steps is to identify the most suitable location for your wind power plant. Vestas' SiteHunt® is an advanced analytical tool that examines a broad spectrum of wind and weather data to evaluate potential sites and establish which of them can provide optimum conditions for your project.

In addition, SiteDesign® optimises the layout of your wind power plant. SiteDesign® runs Computational Fluid Dynamics (CFD) software on our powerful in-house supercomputer Firestorm to perform simulations of the conditions on site and analyse their effects over the whole operating life of the plant. Put simply, it finds the optimal balance between the estimated ratio of annual revenue to operating costs over the lifetime of your plant, to determine your project's true potential and provide a firm basis for your investment decision.

The complexity and specific requirements of grid connections vary considerably across the globe, making the optimal design of electrical components for your wind power plant essential. By identifying grid codes early in the project phase and simulating extreme operating conditions, Electrical PreDesign provides you with an ideal way to build a grid compliant, productive and highly profitable wind power plant. It allows customised collector network cabling, substation protection and reactive power compensation, which boost the cost efficiency of your business.

Advanced monitoring and real-time plant control
All our wind turbines can benefit from VestasOnline® Business, the latest Supervisory Control and Data Acquisition (SCADA) system for modern wind power plants.

This flexible system includes an extensive range of monitoring and management functions to control your wind power plant. VestasOnline® Business enables you to optimise production levels,

+27,000

The Vestas Performance and Diagnostics Centre monitors more than 27,000 turbines worldwide. We use this information to continually develop and improve our products and services.

monitor performance and produce detailed, tailored reports from anywhere in the world. The VestasOnline® Power Plant Controller offers scalability and fast, reliable real-time control and features customisable configuration, allowing you to implement any control concept needed to meet local grid requirements.

Surveillance, maintenance and service

Operating a large wind power plant calls for efficient management strategies to ensure uninterrupted power production and to control operational expenses. We offer 24/7 monitoring, performance reporting and predictive maintenance systems to improve turbine performance and availability. Predicting faults in advance is essential, helping to avoid costly emergency repairs and unscheduled interruptions to energy production.

Our Condition Monitoring System (CMS) assesses the status of the turbines by analysing vibration signals. For example, by measuring the vibration of the drive train, it can detect faults at an early stage and monitor any damage. This information allows pre-emptive maintenance to be carried out before the component fails, reducing repair costs and production loss.

Additionally, our Active Output Management® (AOM) concept provides detailed plans and long term agreements for service and maintenance, online monitoring, optimisation and troubleshooting. It is possible to get a full scope contract, combining your turbines' state-of-the-art technology with guaranteed time or energy-based availability performance targets, thereby creating a solid base for your power plant investment. The Active Output Management® agreement provides you with long term and financial operational peace of mind for your business case.

V90-1.8/2.0 MW®
IEC IIA/IEC IIIA
Facts & figures

POWER REGULATION Pitch regulated with variable speed

OPERATING DATA

Rated power	1,800/2,000 kW
Cut-in wind speed	4 m/s
Cut-out wind speed	25 m/s
Re cut-in wind speed	23 m/s
Wind class	IEC IIA/IEC IIIA

Standard operating temperature range from -20°C* to 40°C

SOUND POWER

Maximum	104 dB*

* Noise modes available

ROTOR

Rotor diameter	90 m
Swept area	6,362 m²
Air brake	full blade feathering with 3 pitch cylinders

ELECTRICAL

Frequency	50/60 Hz
Generator type	4-pole (50 Hz)/6-pole (60 Hz) doubly fed generator, slip rings

GEARBOX

Type	two planetary stages and one helical stage

TOWER

Hub heights	80 m (IEC IIA), 95 m (IEC IIA), and 105 m (IEC IIA)

NACELLE DIMENSIONS

Height for transport	4 m
Height installed (incl. CoolerTop®)	5.4 m
Length	10.4 m
Width	3.5 m

HUB DIMENSIONS

Max. transport height	3.4 m
Max. transport width	4 m
Max. transport length	4.2 m

BLADE DIMENSIONS

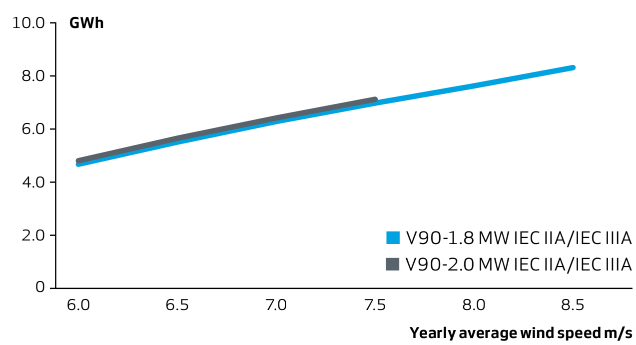
Length	49 m
Max. chord	3.9 m

Max. weight per unit for transportation	70 metric tonnes

TURBINE OPTIONS

- Condition Monitoring System
- Vestas Ice Detection
- Smoke Detection
- Shadow Detection
- Low Temperature Operation to -30°C
- Aviation Lights
- Aviation Markings on the Blades
- Obstacle Collision Avoidance System (OCAS™)

ANNUAL ENERGY PRODUCTION



Assumptions
One wind turbine, 100% availability, 0% losses, k factor =2,
Standard air density = 1.225, wind speed at hub height

V100-1.8/2.0 MW™ IEC IIIA/IEC S Facts & figures

POWER REGULATION	Pitch regulated with variable speed

OPERATING DATA

Rated power	1,800/2,000 kW
Cut-in wind speed	3 m/s
Cut-out wind speed	20 m/s
Re cut-in wind speed	18 m/s
Wind class	IEC IIIA/IEC S
Standard operating temperature range from -20°C* to 40°C	

SOUND POWER

Maximum	105 dB*

* Noise modes available

ROTOR

Rotor diameter	100 m
Swept area	7,854 m²
Air brake	full blade feathering with 3 pitch cylinders

ELECTRICAL

Frequency	50/60 Hz
Generator type	4-pole (50 Hz)/6-pole (60 Hz) doubly fed generator, slip rings

GEARBOX

Type	two planetary stages and one helical stage

TOWER

Hub heights	80 m (IEC IIB/IEC S), 95 m (IEC IIIB/IEC S) and 120 m (IEC IIIA)

NACELLE DIMENSIONS

Height for transport	4 m
Height installed (incl. CoolerTop®)	5.4 m
Length	10.4 m
Width	3.5 m

HUB DIMENSIONS

Max. transport height	3.4 m
Max. transport width	4 m
Max. transport length	4.2 m

BLADE DIMENSIONS

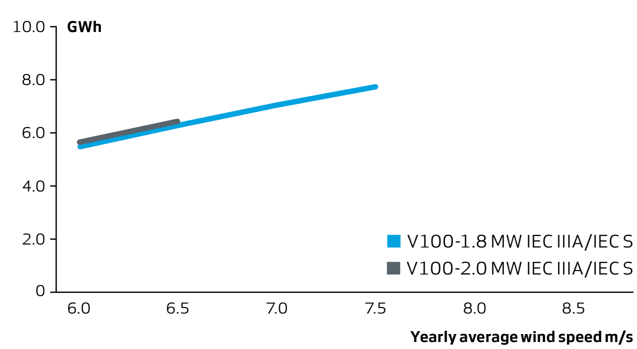
Length	49 m
Max. chord	3.9 m

Max. weight per unit for transportation	70 metric tonnes

TURBINE OPTIONS

- Condition Monitoring System
- Vestas Ice Detection
- Smoke Detection
- Shadow Detection
- Low Temperature Operation to -30°C
- Aviation Lights
- Aviation Markings on the Blades
- Obstacle Collision Avoidance System (OCAS™)

ANNUAL ENERGY PRODUCTION



Assumptions
One wind turbine, 100% availability, 0% losses, k factor =2,
Standard air density = 1.225, wind speed at hub height

V100-2.0 MW®
IEC IIB
Facts & figures

POWER REGULATION — Pitch regulated with variable speed

OPERATING DATA

Rated power	2,000 kW
Cut-in wind speed	3 m/s
Cut-out wind speed	22 m/s
Re cut-in wind speed	20 m/s
Wind class	IEC IIB

Standard operating temperature range from -20°C* to 40°C

SOUND POWER

Maximum	105 dB*

* Noise modes available

ROTOR

Rotor diameter	100 m
Swept area	7,854 m²
Air brake	full blade feathering with 3 pitch cylinders

ELECTRICAL

Frequency	50/60 Hz
Generator type	4-pole (50 Hz)/6-pole (60 Hz) doubly fed generator, slip rings

GEARBOX

Type	two planetary stages and one helical stage

TOWER

Hub heights	80 m (IEC IIB) and 95 m (IEC IIB)

NACELLE DIMENSIONS

Height for transport	4 m
Height installed (incl. CoolerTop®)	5.4 m
Length	10.4 m
Width	3.5 m

HUB DIMENSIONS

Max. transport height	3.4 m
Max. transport width	4 m
Max. transport length	4.2 m

BLADE DIMENSIONS

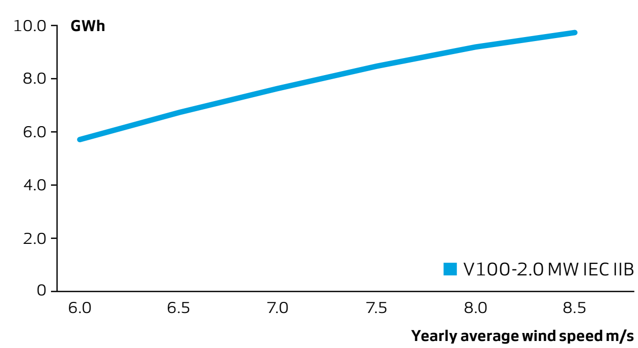
Length	49 m
Max. chord	3.9 m

Max. weight per unit for transportation	70 metric tonnes

TURBINE OPTIONS

- Power Mode (site specfic)
- Condition Monitoring System
- Vestas Ice Detection
- Smoke Detection
- Shadow Detection
- Low Temperature Operation to -30°C
- Aviation Lights
- Aviation Markings on the Blades
- Obstacle Collision Avoidance System (OCAS™)

ANNUAL ENERGY PRODUCTION



Assumptions
One wind turbine, 100% availability, 0% losses, k factor =2,
Standard air density = 1.225, wind speed at hub height

V110-2.0 MW™ IEC IIIA Facts & figures

POWER REGULATION — Pitch regulated with variable speed

OPERATING DATA

Rated power	2,000 kW
Cut-in wind speed	3 m/s
Cut-out wind speed	20 m/s
Re cut-in wind speed	18 m/s
Wind class	IEC IIIA

Standard operating temperature range from -20°C* to 40°C

SOUND POWER

Maximum	107.6 dB*

* Noise modes available

ROTOR

Rotor diameter	110 m
Swept area	9,503 m²
Air brake	full blade feathering with 3 pitch cylinders

ELECTRICAL

Frequency	50/60 Hz
Generator type	4-pole (50 Hz)/6-pole (60 Hz) doubly fed generator, slip rings

GEARBOX

Type	two planetary stages and one helical stage

TOWER

Hub heights	80 m (IEC IIIA), 95 m (IEC IIIA/IEC IIIB), 110 m (IEC IIIB), 120 m (IEC IIIB) and 125 m (IEC IIIB)

NACELLE DIMENSIONS

Height for transport	4 m
Height installed (incl. CoolerTop®)	5.4 m
Length	10.4 m
Width	3.5 m

HUB DIMENSIONS

Max. transport height	3.4 m
Max. transport width	4 m
Max. transport length	4.2 m

BLADE DIMENSIONS

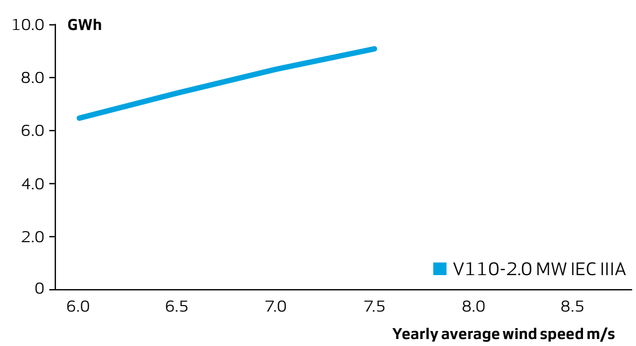
Length	54 m
Max. chord	3.9 m

Max. weight per unit for transportation	70 metric tonnes

TURBINE OPTIONS

- Power Mode (site specific)
- Condition Monitoring System
- Vestas Ice Detection
- Smoke Detection
- Shadow Detection
- Low Temperature Operation to -30°C
- Aviation Lights
- Aviation Markings on the Blades
- Obstacle Collision Avoidance System (OCAS™)

ANNUAL ENERGY PRODUCTION



Assumptions
One wind turbine, 100% availability, 0% losses, k factor =2,
Standard air density = 1.225, wind speed at hub height

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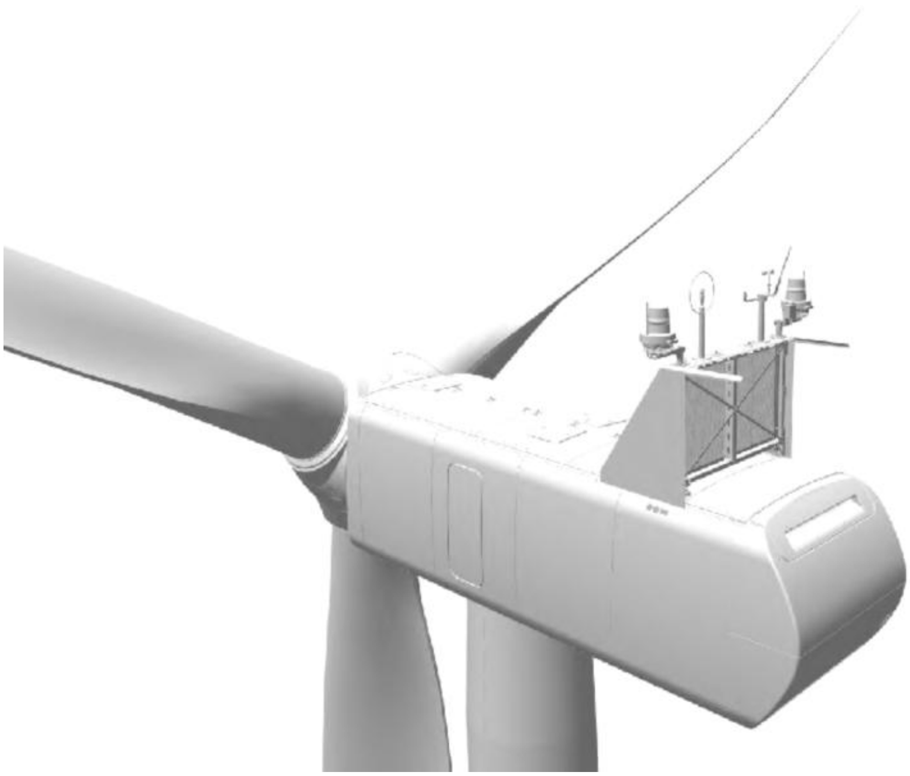
General specification
2.0/2.2MW V110/100 50/60Hz



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See general reservations, notes, and disclaimers to this general specification in section General reservations, notes, and disclaimers, p. 21.

1 Abbreviations and technical terms

Abbreviation	Explanation
AEP	Annual Energy Production
EMC	Electromagnetic Compatibility
HH	Hub Height
HV	High Voltage
LPS	Lightning Protection System
MASL	Meters Above Sea Level
MW	Megawatt
OH&S	Occupational Health & Safety
OVRT	Over Voltage Ride-Through
pu	Per unit
rpm	Revolutions per minute
SSR-P	Sub Synchronous Resonance Protection
UVRT	Under Voltage Ride-Through

Table 1-1: Abbreviations

Term	Explanation
None	

Table 1-2: Explanation of terms

2 General description

The Vestas 2.0MW series wind turbine is a pitch-regulated upwind turbine with active yaw, gearbox and a three-blade rotor. The turbine is available in two rotor diameters 100 or 110m with a generator rated at 2.0 or 2.2MW. The turbine utilises a microprocessor pitch control system called OptiTip® and the OptiSpeed™ (variable speed) feature. With these features, the wind turbine is able to operate the rotor at variable speed (rpm), helping to maintain output at or near rated power.

<table>
<tr><th rowspan="2">Rotor</th><th rowspan="2">Rating [MW]</th><th rowspan="2">Wind Class [IEC]</th><th colspan="2">Hub Height [m]</th></tr>
<tr><th>50Hz</th><th>60Hz</th></tr>
<tr><td rowspan="3">V100</td><td rowspan="2">2.0</td><td>IIB</td><td>80, 95</td><td>80, 95</td></tr>
<tr><td>IIC</td><td>80</td><td>80</td></tr>
<tr><td>2.2</td><td>S</td><td>80, 95</td><td>80, 95</td></tr>
<tr><td rowspan="4">V110</td><td rowspan="3">2.0
2.0
2.0</td><td>IIIA</td><td>95</td><td>80, 95</td></tr>
<tr><td>IIIB</td><td>95, 110, 120, 125</td><td>95, 110</td></tr>
<tr><td>IIIC</td><td>80</td><td>80</td></tr>
<tr><td>2.2</td><td>S</td><td>80, 95
110, 120, 125</td><td>80, 95</td></tr>
</table>

Table 2-1: Turbine variants and tower heights

3 Safety

The safety specifications in this safety section provide limited general information about the safety features of the turbine and are not a substitute for Buyer and Buyer's 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 3.11 Manuals and warnings for additional guidance.

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

3.2 Escape

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

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

Escape from the service lift is by ladder.

3.3 Rooms/working areas

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

3.4 Climbing facilities

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

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

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

3.5 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.

3.6 Lighting

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

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

3.7 Emergency stop buttons

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

3.8 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.

3.9 Fire protection/first aid

A CO_2 (recommended) or ABC fire extinguisher and first aid kit must be available in the nacelle during all service and maintenance activities. A fire blanket must be available nearby for all those activities for which the respective work instruction requires it.

3.10 Warning signs

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

3.11 Manuals and warnings

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

4 Type approvals

The turbine will be type-certified according to the certification standards listed below:

- IEC 61400-22

5 Operational envelope and performance guidelines

Actual climate 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.

The turbine can be equipped with different power generation components depending on the region which may influence the performance of the turbine. Consult Vestas Wind Systems for further details.

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

5.1 Climate and site conditions

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

Extreme design parameters				
Wind climate	**V100**		**V110**	
	2MW	**2.2MW**	**2MW**	**2.2MW**
	IEC IIB	**IEC S**	**IEC IIIA**	**IEC S**
Ambient temperature range (standard turbine)	-30° to +50°C	-30° to +50°C	-30° to +50°C	-30° to +50°C
Ambient temperature interval (low temperature turbine)	-40° to +50°C	-40° to +50°C	-40° to +50°C	-40° to +50°C
Extreme wind speed (10-minute average)	42.5 m/s	42.5 m/s	37,5 m/s	37,5 m/s
Survival wind speed (3-second gust)	59.5 m/s	59.5 m/s	52,5 m/s	52,5 m/s

Table 5-1: Extreme design parameters

Average design parameters				
Wind climate	**V100**		**V110**	
	2MW	**2.2MW**	**2MW**	**2.2MW**
	IEC IIB	**IEC S**	**IECA**	**IEC S**
Annual average wind speed	8.5 m/s	7,5 m/s	7,5 m/s	6,5 m/s
Form factor, c	2.0	2,2	2,0	2,0
Turbulence intensity according to IEC 61400-1:2005, including wind farm turbulence (@15 m/s – 90% quartile)	16%	16%	18%	18%
Wind shear	0.20	0.20	0.20	0.20
Inflow angle (vertical)	8°	8°	8°	8°

Table 5-2: Average design parameters

5.1.1 Complex terrain

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

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

5.1.2 Altitude

The turbine is designed for use at altitudes up to 1500 metres above sea level as standard.

With altitudes above 1500 metres, special considerations must be taken regarding for example HV installations and cooling performance. Consult Vestas for further information.

5.1.3 Wind farm layout

Turbine spacing is to be evaluated site-specifically. Spacing below three rotor diameters (2D) may require sector-wise curtailment.

5.2 Operational envelope (temperature and wind)

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

Operational envelope (temperature and wind)				
Wind climate	V100		V110	
	2MW	2.2MW	2MW	2.2MW
	IEC IIB	IEC S	IECA	IEC S
Ambient temperature interval (standard temperature turbine)	-20° to +40°C	-20° to +40°C[1]	-20° to +40°C	-20° to +40°C[1]
Ambient temperature interval (low temperature turbine)[1]	-30° to +40°C	-30° to +40°C[1]	-30° to +40°C	-30° to +40°C[1]
Cut-in (10 minute average)	3 m/s	3 m/s	3 m/s	3 m/s
Cut-out (10 minute average)	22 m/s	22 m/s	20 m/s	20 m/s
Re-cut in (10 minute average)	20 m/s	20 m/s	18 m/s	18 m/s

Table 5-3: Operational envelope (temperature and wind)

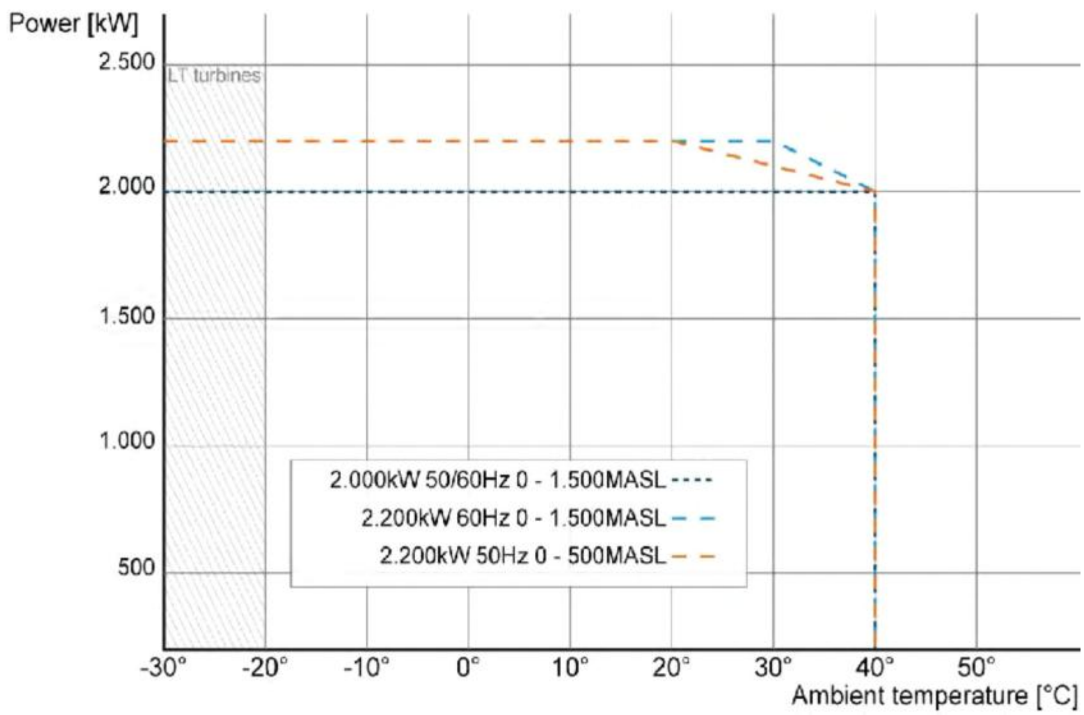

Figure 5-1: Temperature and de-rate curves

[1] Limitation in high temperature performance will apply for IEC S turbines

5.3 Operational envelope (grid connection)

Operational envelope (grid connection)		
Nominal phase voltage	[U_{NP}]	400 V
Nominal frequency	[f_N]	50 / 60Hz
Maximum frequency gradient	±4 Hz/sec.	
Maximum negative sequence voltage	3% (connection) 2% (operation)	
Minimum required short circuit ratio at turbine HV connection	5%	
Maximum short circuit current contribution	1.45 pu (peak)	

Table 5-4: Operational envelope (grid connection)

Generator and converter disconnecting values		
	50Hz	**60Hz**
Frequency is above [Hz] for 0.2 Seconds	53 Hz	63,6Hz
Frequency is below [Hz] for 0.2 Seconds	47 Hz	56,4Hz

Table 5-5: Generator and converter disconnecting values

NOTE Over the turbine lifetime, grid drop-outs are to occur at an average of no more than 50 times a year.

5.4 Reactive power capability

The turbine has a reactive power capability dependent on power rating as illustrated in Figure 5-2 and Figure 5-3.

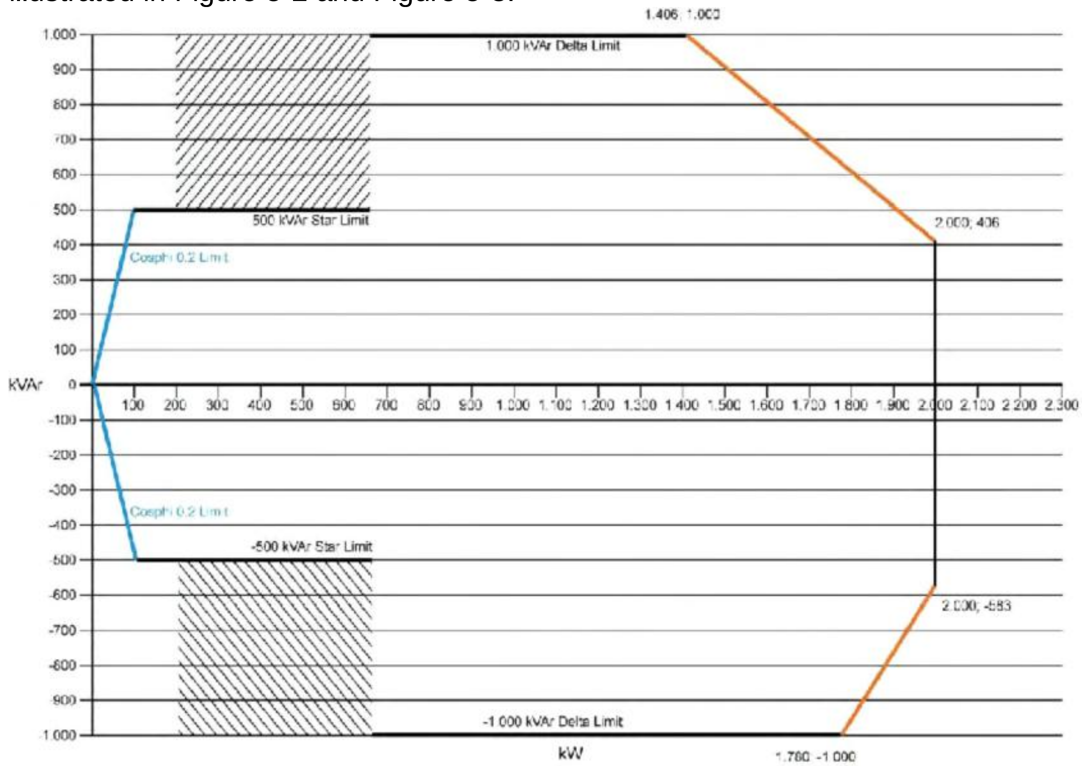

Figure 5-2: Reactive power capability for 2.0MW variants 50 and 60Hz

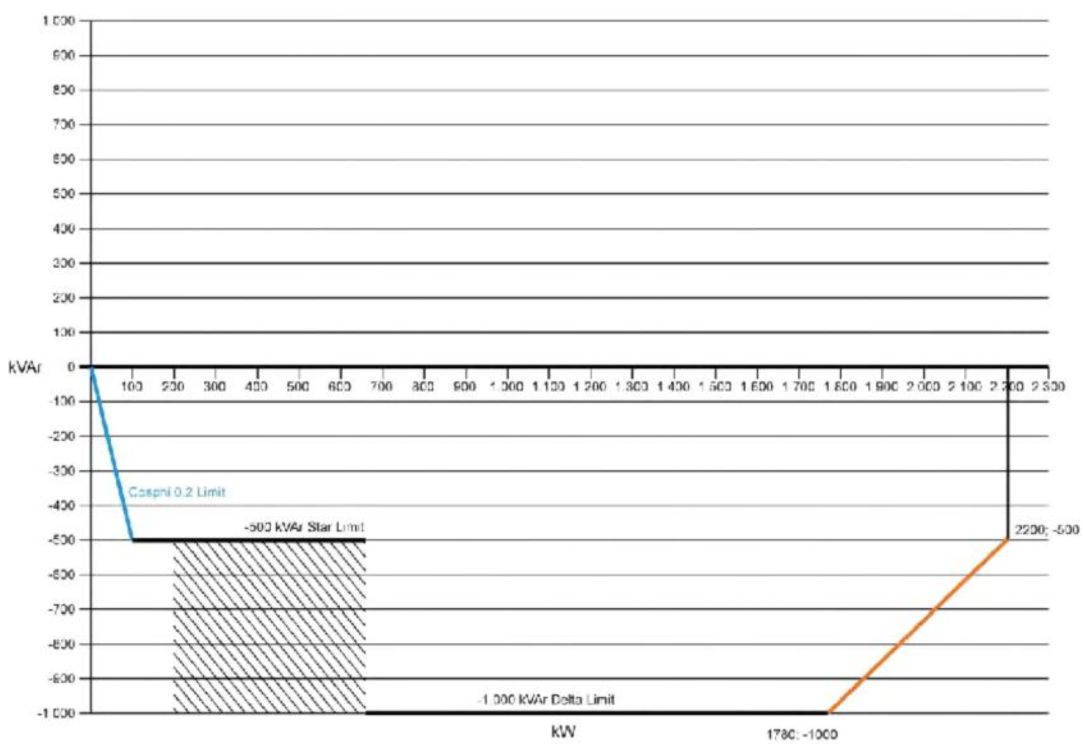

Figure 5-3: Reactive power capability for 2.2MW variants 50 and 60Hz

The above chart applies to the low-voltage side of the HV transformer. The turbine maximises active power or reactive power depending on grid voltage conditions.

5.5 Fault ride through

5.5.1 UVRT

The turbine is equipped with a reinforced converter system in order to gain better control of the generator during grid faults. The turbine control system continues to run during grid faults.

The pitch system is optimised to keep the turbine within normal speed conditions, and the generator speed is accelerated in order to store rotational energy and be able to resume normal power production faster after a fault and keep mechanical stress on the turbine at a minimum.

The turbine is designed to stay connected during grid disturbances within the UVRT curve in Figure 5-4, p. 12.

Power recovery time	
Power recovery to 90% of pre-fault level	Maximum 2 seconds

Table 5-6: Power recovery time

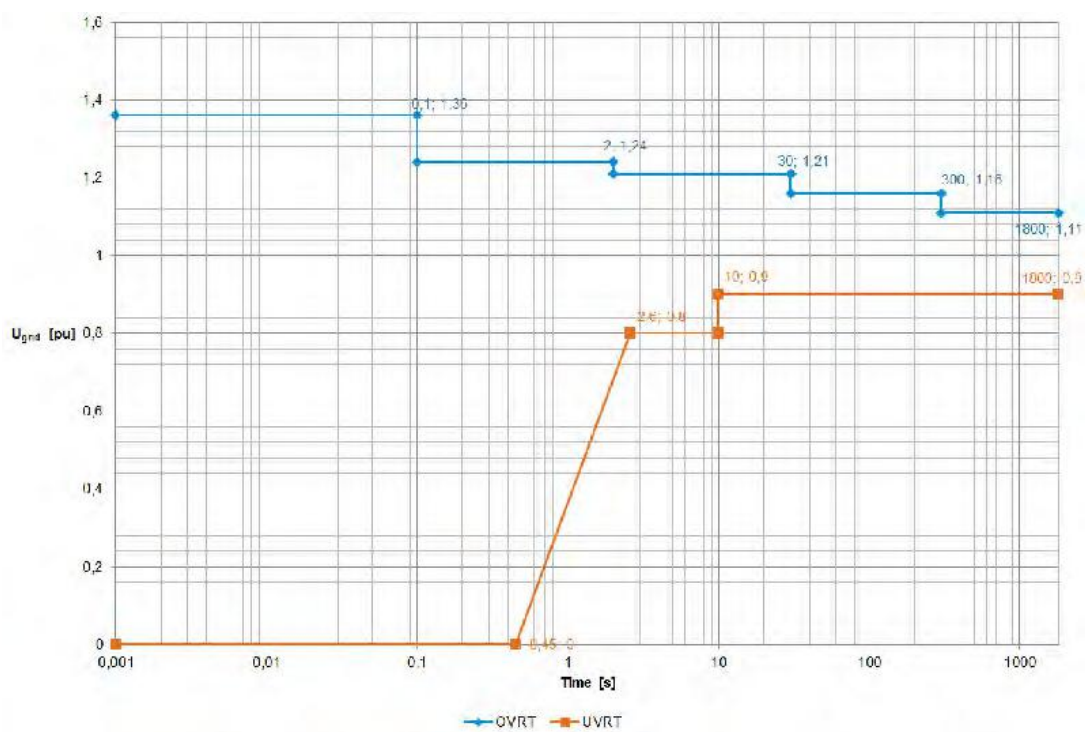

Figure 5-4: OVRT, UVRT curves for symmetrical and asymmetrical faults where U_{grid} represents grid voltage values

The turbine stays connected when the values are above UVRT (and protection) and below OVRT.

5.5.2 OVRT

The turbine is able to run with voltage levels above nominal within restricted time intervals.

The generator and the converter will be disconnected if the voltage level exceeds the OVRT curve shown in Figure 5-4.

5.5.3 Reactive current contribution

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

Symmetrical reactive current contribution

During symmetrical voltage dips the wind farm will inject reactive current to support the grid voltage. The reactive current injected is a function of the voltage measured at the low voltage side of the WTG transformer.

The default value gives a reactive current part of 1 p.u. of the nominal WTG current. Figure 5-5 indicates the reactive current contribution as a function of the voltage. The reactive current contribution is independent from the actual wind conditions and pre-fault power level.

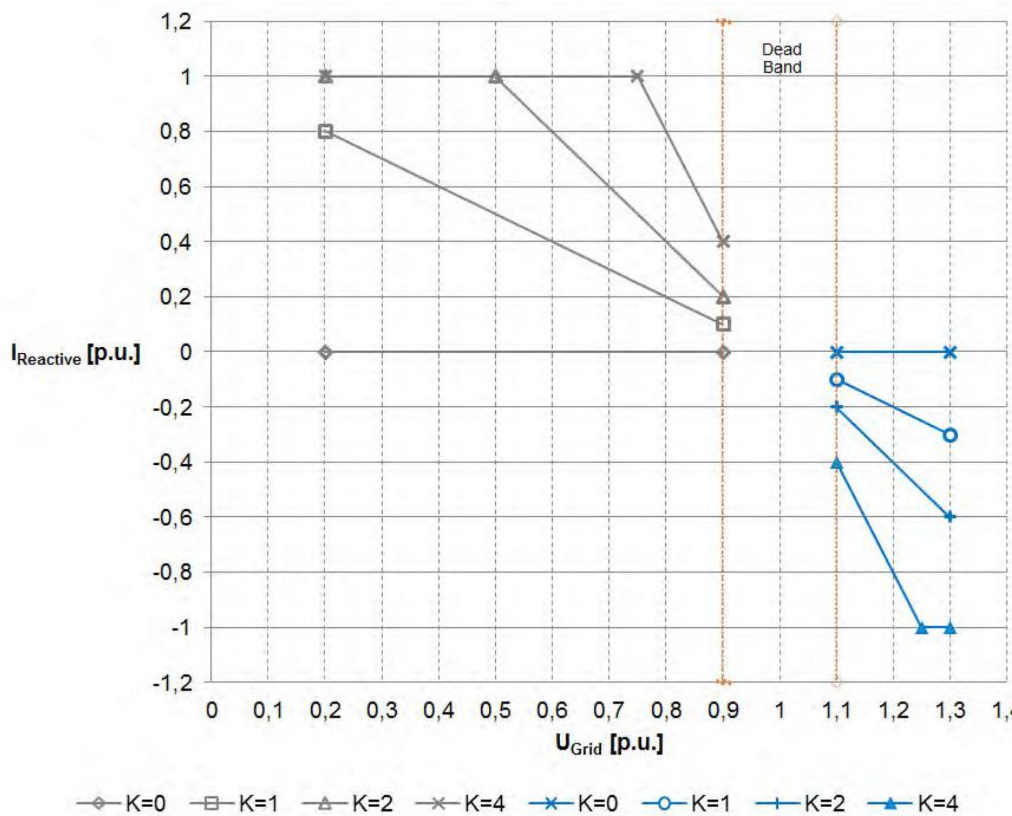

Figure 5-5: Reactive current contribution

Slope (K-factor), offset and dead band can be set freely to fulfil requirements to UVRT current injection.

Asymmetrical reactive current contribution

Current reference values are controlled during asymmetrical faults to ensure ride through.

5.5.4 Sub synchronous resonance protection

Turbine is equipped with fast-acting protection to shield the converter, generator and drivetrain from excessive voltages, currents and torques due to sub-synchronous resonance (SSR) caused by interaction between the turbine and the series-capacitor-compensated transmission lines. The generator and converter will be disconnected upon SSR detection by the turbine controller, according to Table 5-7: SSR protection time. SSR protections availability is depending on grid conditions at the specific sites.

SSR protection time	
Generator and converter disconnect	Maximum 100ms (including breaker response time)

Table 5-7: SSR protection time

5.6 Active and reactive power control

The turbine is designed for control of active and reactive power by means of the VestasOnline® SCADA system.

Maximum ramp rates for external control	
Active power[2]	0.1 pu/sec
Reactive power[2]	2.5 pu/sec

Table 5-8: Maximum ramp rates for external control data

To protect the turbine, active power cannot be controlled to values below the curve in Figure 5-6, p. 15.

[2] Limitations in duration of a power ramp may apply.

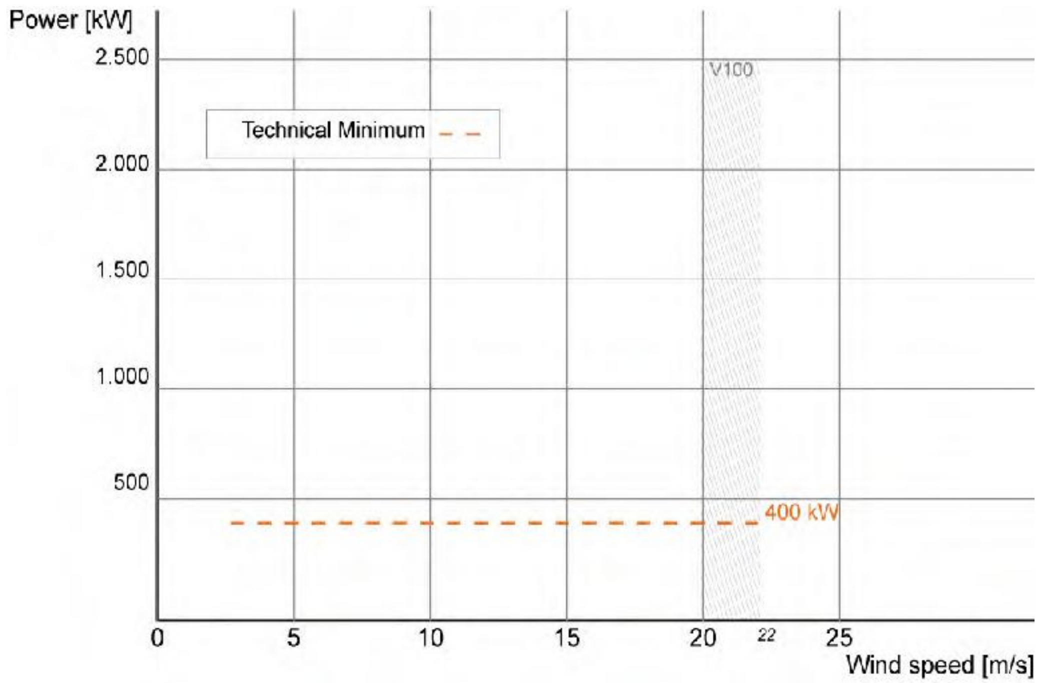

Figure 5-6: Minimum active power output related to wind speed

5.7 Voltage control

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

5.8 Frequency control

The turbine can be configured to perform frequency control by decreasing the output power as a linear function of the grid frequency (over frequency).

Dead band and slope for the frequency control function are configurable.

5.9 High voltage connection

5.9.1 Transformer

The step-up HV transformer is located in a separate locked room in the back of the nacelle.

The transformer is a three-phase, two-winding, dry-type transformer that is self-extinguishing. The windings are delta-connected on the high-voltage side unless otherwise specified.

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

- The transformer is as default designed according to IEC standards for both 50 Hz and 60Hz versions.
- For turbines installed in Member States of the European Union, it is required to fulfil the Ecodesign regulation No 548/2014 set by the European Commission.

5.9.2 HV Switchgear (Option)

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

The switchgear is available in two variants with increasing features – see *Table 5-9 - HV switchgear variants and features*. Beside the increase in features, the switchgear can be configured depending on the number of grid cables planned to enter the individual turbine. The design of the switchgear solution is optimized such grid cables can be connected to the switchgear even before the tower is installed and still maintain its protection toward weather conditions and internal condensation due to a gas tight packing.

The switchgear is available in an IEC version and in an IEEE version. The IEEE version is however only available in the highest voltage class.

HV Switchgear		
Variant	**Basic**	**Streamline**
IEC standards	○	⦿
IEEE standards	⦿	○
Vacuum circuit breaker panel	⦿	⦿
Overcurrent, short-circuit and earth fault protection	⦿	⦿
Disconnector / earthing switch in circuit breaker panel	⦿	⦿
Voltage Presence Indicator System for circuit breaker	⦿	⦿
Voltage Presence Indicator System for grid cables	⦿	⦿
Double grid cable connection	⦿	⦿
Triple grid cable connection	⦿	○
Preconfigured relay settings	⦿	⦿
Turbine safety system integration	⦿	⦿
Redundant trip coil circuits	⦿	⦿
Trip coil supervision	⦿	⦿
Pendant remote control from outside of tower (Option via ground controller)	⦿	⦿
Sequential energisation	⦿	⦿
Reclose blocking function	⦿	⦿
Heating elements	⦿	⦿
Trapped-key interlock system for circuit breaker panel	⦿	⦿
UPS power back-up for protection circuits	⦿	⦿
Motor operation of circuit breaker	⦿	⦿
Cable panel for grid cables (configurable)	○	⦿
Switch disconnector panels for grid cables – max three panels (configurable)	○	⦿
Earthing switch for grid cables	○	⦿
Internal arc classification	○	⦿
Supervision on MCB’s	○	⦿

Table 5-9 - HV switchgear variants and features

5.10 Main contributors to 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:

Main contributors to own consumption	
Hydraulic motor	20 kW
Yaw motors 6 x 1.75 kW	10.5 kW
Oil heating 3 x 0.76 kW	2.3 kW
Air heaters (2 x 6 kW)	12 kW
Oil pump for gearbox lubrication	5.0 kW
Generator fans (included in generator efficiency)	7.0 kW
Average of measured no-load loss of the HV transformer	4.0 kW

Table 5-10: Own consumption data

6 Drawings

6.1 Structural design – illustration of outer dimensions

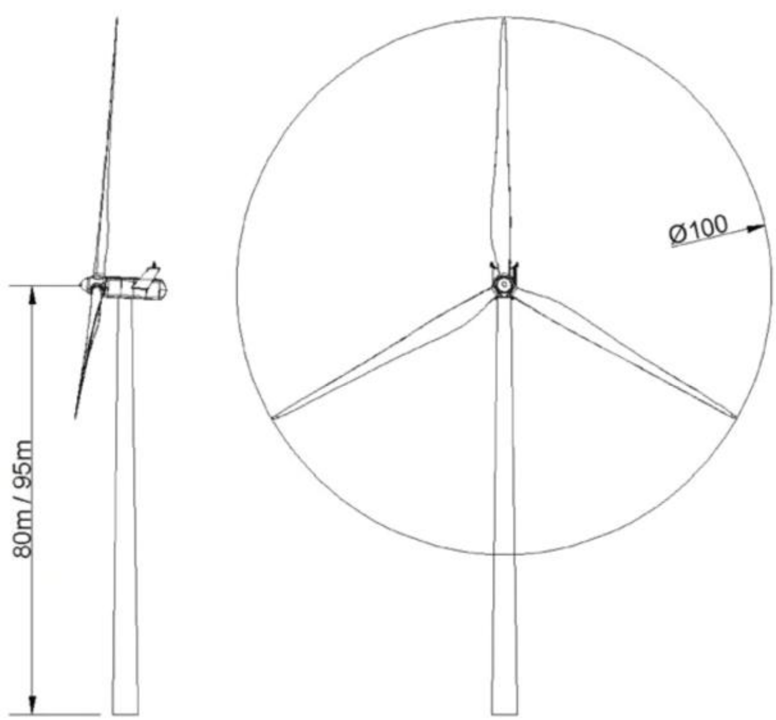

Figure 6-1: Illustration of outer dimensions for a V100 turbine

6.2 Structural design (side-view drawing)

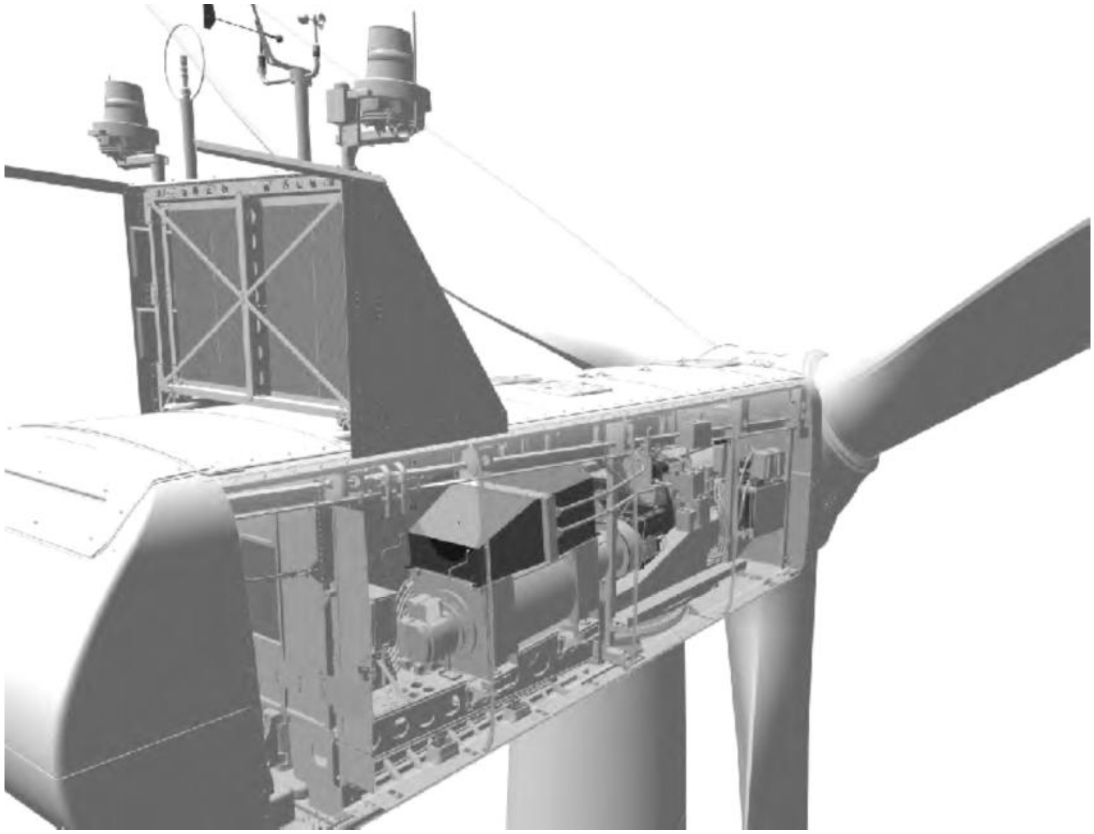

Figure 6-2: Side-view drawing

6.3 Turbine protection systems

6.3.1 Braking concept

The main brake on the turbine is aerodynamic. Braking the turbine is done by feathering the three blades. During emergency stop all three blades will feather simultaneously to full end stop, thereby slowing the rotor speed.

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.

6.4 Overspeed protection

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

In addition, the turbine is equipped with a safety PLC, an independent computer module that measures the rotor rpm. In case of an overspeed situation, the safety PLC activates the emergency feathered position (full feathering) of the three blades independently of the turbine controller.

6.5 EMC system

The turbine and related equipment must fulfil the EU EMC-directive with later amendments:

- European Parliament Council directive 2004/108/EC of 15 December 2004 on the approximation of the laws of the Member States relating to electromagnetic compatibility.
- The EMC-directive with later amendments.

6.6 Lightning protection system

The LPS consists of three main parts.

- Lightning receptors.
- Down conducting system.
- Earthing system.

NOTE The LPS is designed according to IEC standards.

6.7 Earthing

The Vestas Earthing System is based on foundation earthing.

Document 0000-3388 ‘Vestas Earthing System’ contains the list of documents pertaining to the Vestas Earthing System.

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

7 Environment

7.1 Chemicals

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

- 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.

8 General reservations, notes, and disclaimers

-
- The general specification document here described applies to the present design of the 2.0MW wind turbine series. Updated versions of the wind turbine, which may be manufactured in the future, may have a general specification document that differs from these general specifications. In the event that Vestas supplies an updated version of the wind turbine, Vestas will provide updated general specification applicable to the updated version.
- Vestas recommends that the 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 (for example wind speeds and temperatures) are equipped with hysteresis control. This can, in certain borderline situations, result in turbine stops even though the ambient conditions are within the listed operation parameters.
- The earthing system must comply with the minimum requirements from Vestas, and be in accordance with local and national requirements, and codes of standards.
- This document, 'General Specifications', is not an offer for sale, and does not contain any guarantee, warranty, and/or verification of the power curve and noise (including, without limitation, the power curve and noise verification method). Any guarantee, warranty, and/or verification of the power curve and noise (including, without limitation, the power curve and noise verification method) must be agreed to separately in writing.

9 Appendices

9.1 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 ANSI/ASSE Z359.1-2007
Bed frame	IEC 61400-1:2005
Tower	IEC 61400-1:2005 Eurocode 3

Table 9-1: Structural design codes

9.2 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 with rules in ISO 81400-4
Blades	DNV-OS-J102 IEC 1024-1 IEC 60721-2-4 IEC 61400 (Part 1, 12, 22 and 23) DEFU R25 ISO 2813 DS/EN ISO 12944-2

Table 9-2: Mechanical equipment design codes

9.3 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 60831
Insulating bushings for AC voltage above 1 kV	IEC 60137
Insulation coordination	BS EN 60071

Design codes – electrical equipment	
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 60076-11
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 and IEC 72A
Classification of insulation, materials for electrical machinery	IEC 85
Safety of machinery – electrical equipment of machines	IEC 60204-1

Table 9-3: Electrical equipment design codes

9.4 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 9-4: I/O network system design codes

9.5 Design codes – EMC system

To fulfil EMC requirements the design must be as recommended for lightning protection. See section 9.6 Design codes – lightning , p. 24.

Design codes – EMC system	
Designed according to	IEC 61400-1: 2005
Further robustness requirements according to	TPS 901795

Table 9-5: EMC system design codes

9.6 Design codes – lightning protection

The LPS is designed according to lightning protection level 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 61400-24:2010

Table 9-6: Lightning protection design codes

9.7 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.

9.8 Operational envelope conditions for power curve (at hub height)

Conditions for power curve (at hub height)	
Wind shear	0.00-0.30 (10 minute average)
Turbulence intensity	6-12% (10 minute average)
Blades	Clean
Rain	No
Ice/snow on blades	No
Leading edge	No damage
Terrain	IEC 61400-12-1
Inflow angle (vertical)	0 ±2°

Table 9-7: Conditions for power curve

9.9 Power curves, C_t values, and sound power levels

Power curve, C_t values and sound power levels for noise modes are defined in separate performance specifications for each variant. The documents will reference this General Specification to ensure correct traceability between performance data sheet and the General Specification.

The turbine can be equipped with different power generation components depending on the region which may influence the performance of the turbine. Consult Vestas Wind Systems for further details.

The Performance Specifications are listed below:

Performance specifications	Number
V100-2.2MW 50/60Hz	0051-0204
V110-2.2MW 50/60Hz	0051-0205
V100-2.0MW 50/60Hz	0051-0207
V110-2.0MW 50/60Hz	0051-0208

Table 9-8: Performance specifications