G87-2.0 MW

Maximum output at minimum cost per kWh for medium and low wind sites

Advantages

- Optimum price-quality ratio provided by Gamesa's vertically integrated supply structure
- State-of-the-art blade manufacturing technology using carbon fibre and pre-preg technology for a lighter rotor design
- IEC IIA/WZII classes with the largest swept area
- Exceptional service facility through an independent drive train
- Reduced sound level for standard power level and different low-noise level versions
- Gamesa Technology with a proven track-record in complex terrains: active yaw, optimised control, fast pitch dynamics

Gamesa Eólica

Rotor

Diameter	87 m
Swept area	5,945 m^2
Rotational speed, rotor	9.0 - 19.0 r.p.m.
Rotational direction	Clockwise (frontal view)

Blades

Number of blades	3
Length	42,5 m
Airfoils	DU (Delft University) + FFA-W3
Material	Preimpregnated epoxy glass fibre + carbon fibre
Total blade weight	Approx. 6,500 kg

Gearbox G87-2.0 MW

Type	1-stage planetary / 2-stage helical
Ratio	50 Hz 1:100.5 60 Hz 1:120.515
Cooling	Oil pump with heat exchanger
Oil heater	2.2 kW

2.0 MW Generator

Type	Doubly fed generator
Rated power	2.0 MW
Voltage	690 V ac
Frequency	50 Hz / 60 Hz
Protection class	IP 54
Number of poles	4
Rotation speed	900:1,900 r.p.m. (rated/1,680 r.p.m.)
Rated current	
Stator	1,500 A @ 690 V
Rated power factor, default	1.0
Power factor range	0.98 CAP - 0.96 IND (option)

Weights

Class	IEC IIA Dibt WZII	IEC IIA Dibt WZII	IEC IIA Dibt WZII
Tower height	67 m	78 m	100 m
Tower (tubular)	153 T	200 T	286 T
Nacelle	65 T	65 T	65 T
Rotor (incl. hub)	38 T	38 T	38 T
TOTAL	**256 T**	**303 T**	**389 T**

Control System

The Generator is a doubly fed machine (DFM), whose speed and power is controlled through IGBT converters and PWM (Pulse Width Modulation) electronic control.
Advantages:

- Active and reactive power control.
- Low harmonics content and minimum losses.
- Increased efficiency and production.
- Prolonged working life of the turbine.

Remote Control System

A remote control system that ensures real-time monitoring of the machines' parameters as well as communication with the weather masts and the electrical sub-station from a central or remote site. Ability for controlling active and reactive power.

Predictive Maintenance System SMP-8C

Predictive Maintenance System for the early detection of wear and faults in the wind turbine's main components.
Advantages:

- Capacity for signal processing and detection of alarms within the equipment.
- Integration within the control system.
- Reduction in major corrective measures.
- Increase in the availability and working life of the machine.
- Preferential terms in negotiations with insurance companies.

Grid Code Compliance

Dynamic regulation of active and reactive power in order to contribute to the stability of the grid and overcome voltage dips by means of a device that ensures grid code compliance.

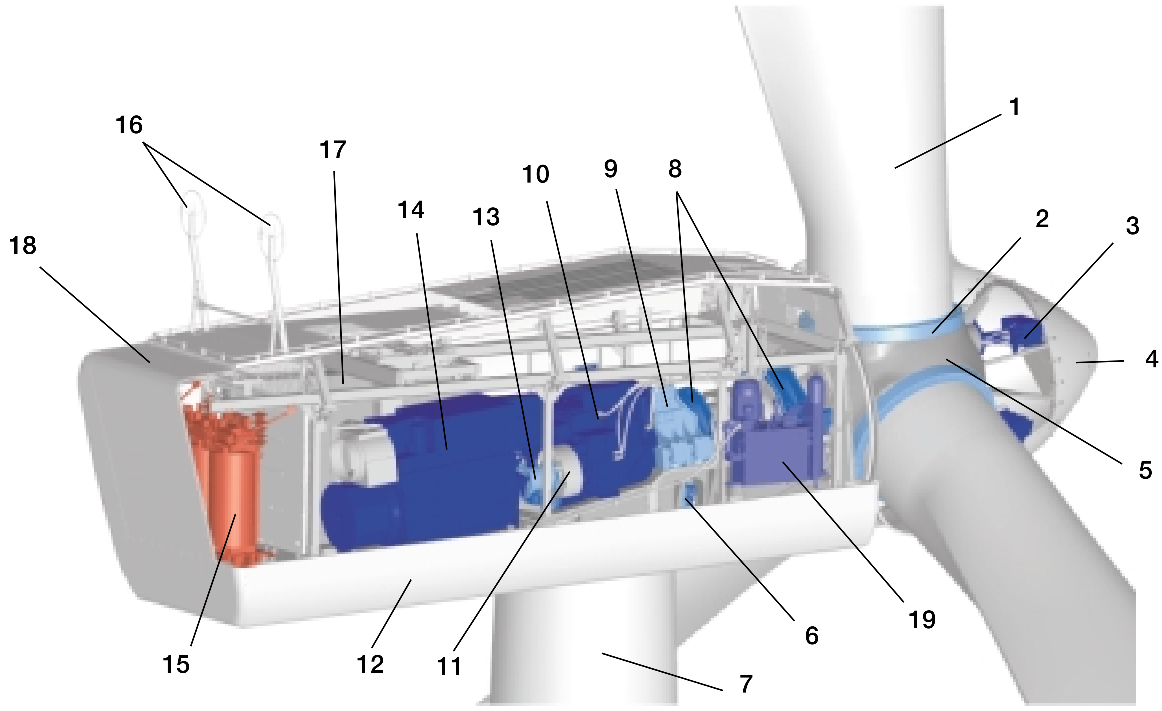
The wind turbine is equipped with an active crowbar system that maintains connection during voltage dips in the supply system.

Brake

Aerodynamic primary brake by feathering of blades. In addition, mechanical emergency disc brake hydraulically activated and mounted on the gearbox's high-speed shaft.

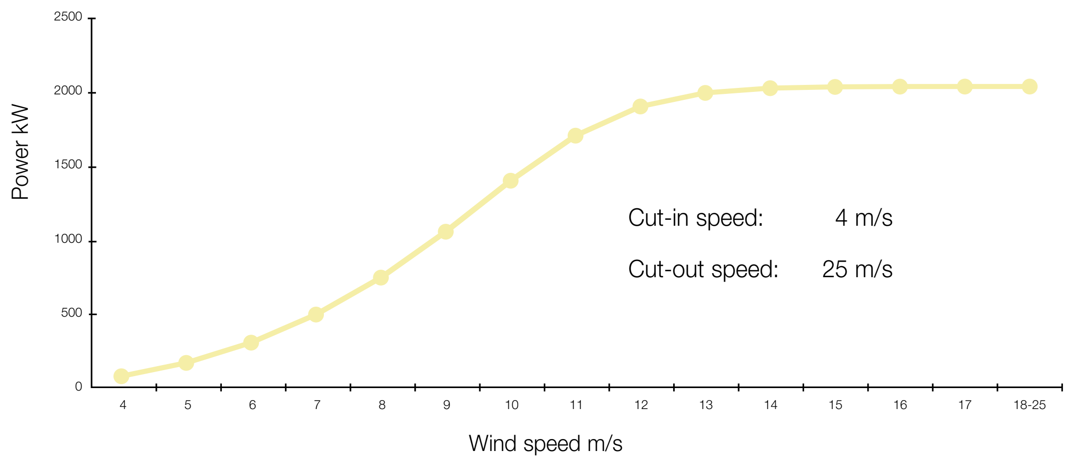
Lightning protection

The G87 wind turbine generator uses the "total lightning protection" system, according to IEC 1024-1 standard. This system conducts the lightning from both sides of the blade tip down to the root joint and from there to the nacelle, tower and earthing system. Therefore, the blade is protected and electrical component damage is avoided.



1. Blade
2. Blade bearing
3. Hydraulic pitch actuator
4. Hub cover
5. Hub
6. Active yaw control
7. Tower
8. Main bearing house
9. Gear tie rod
10. Gearbox
11. Main disc brake
12. Nacelle support frame
13. Cardan or composite shaft
14. Doubly fed generator
15. Transformer
16. Anemometer and wind vane
17. Top controller
18. Nacelle cover
19. Hydraulic unit

Power curve G87-2.0 MW (for an air density of 1.225 kg/m³ and a sound level of 105.3 dB(A))



Power curve calculation based on DU (Delft University) and FFA-W3 airfoil data.

Calculation parameters: 50Hz grid frequency; pitch regulated tip angle (pitch control), a 10% turbulence intensity and variable rotor speed ranging from 9.0 – 19.0 r.p.m.

Reduced sound level versions. The G87-2.0 MW wind turbine is supplied in different low-noise versions: 104 dB(A), 103dB(A), 102dB(A), 101dB(A).

Gamesa Eólica

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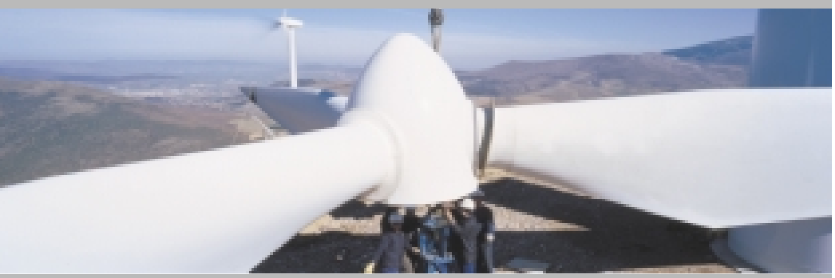

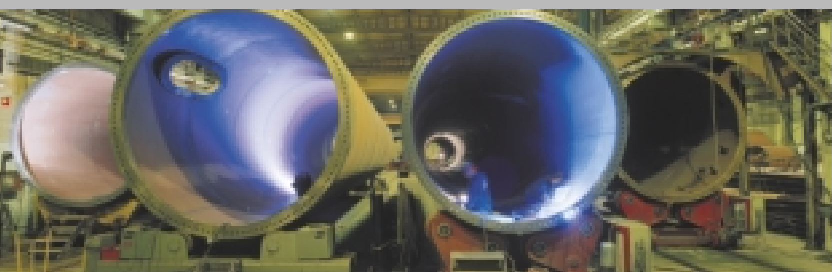

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1. Wind-turbine description

The Gamesa Eólica's G87–2.0 MW wind-turbine is a three bladed, upwind, pitch regulated and active yaw wind-turbine. It has a rotor diameter of 87 m and uses the control system concept that enables the wind-turbine to operate in a broad range of variation of rotor speed.

The rotor has three-blades with full span control, pitch bearings and the nodular cast iron hub.

The blades are 42,5m span and are made of carbon and glass fibre reinforced epoxy using the pre-preg moulding technology. Each blade consists of two blade shells, bonded to a supporting beam. Special steel inserts connect the blade to the blade bearing. This bearing is a 4– point ball type bolted to the hub.

The rotor pitch is variable. This feature provides fine adjustment of the blade-operating angle at all times with respect to power production and noise emission.

At high wind speeds the control system and the pitch system keep the power output at its nominal value, independently of air temperature and air density. At lower wind speeds the variable pitch system and the control system maximise the power output by choosing the combination of rotor speed and pitch angle which give maximum power coefficient.

The main shaft transmits the power to the generator through the gearbox. The gearbox is a 3-combined-stages, one planetary and two helical parallel shafts, gearbox. From it the power is transmitted via a flexible coupling to the generator.

The generator is a high efficiency 4–pole doubly fed generator with wound rotor and slip rings.

The wind-turbine primary brake is given by full feathering the blades. The individual pitch system gives a triple redundant safety system. The mechanical brake is a parking disc brake system hydraulically activated and mounted on the gearbox high-speed shaft.

All functions of the wind turbine are monitored and controlled by several microprocessor based control units. The controller system is placed in the nacelle. Blade pitch angle variation is regulated by a hydraulic system actuator which enables the blade to rotate 95º. This system also supplies pressure to the brake system and to the yaw retention brake system.

The yaw system consists of four gears electrically operated and controlled by the wind turbine controller based on information received from the ultra-sonic anemometers mounted on top of the nacelle. The yaw gears rotate the yaw pinions, which mesh with a large toothed yaw ring mounted on the top of the tower. The yaw bearing is a plain bearing system with hydraulic and mechanical devices to provide retention torque.

The nacelle cover -made of glass fibre reinforced polyester- protects all the components inside against rain, snow, dust, sun, etc. Access to the nacelle from the tower is through a central opening. The nacelle houses the internal 800kg service crane, which can be enlarged to hoist the main components (8000kg).

The steel tubular tower is delivered painted (see Section 4.13 for more details). GAMESA EOLICA, S.A. offers a service lift in the tubular tower.

1.1 Control system

The control system ensures that both the rotor speed and the drive torque of the wind turbine always transform into a steady and stable electric power eventually injected into the grid. This control system also obtains a unitary power factor to the grid.

The control system consists of an effective asynchronous generator with wound rotor, slip rings, two 4-quadrant converters with IGBT switches, contactors and protection. Because the way this generator is controlled it is seen from the grid (i.e., from the stator) as a synchronous generator.

The generator is protected against short-circuits and overloading. The temperatures are also continuously monitored by PT100's in stator hotspot points and bearings.

The generator in the control system is a special asynchronous generator which is able to run with variable speed and simultaneously keep the power constant. This feature is achieved by control of the rotor currents. By means of controlling of the these currents, the power factor can be viewed as a configurable parameter of the control system. As a result the losses in the electrical grid decrease.

Another result of the synchronous generation that characterizes the control system is the "soft" connection to the grid which means a smooth connection/disconnection to grid.

Wind-turbine G87–2.0 MW operates with a variable generator speed range of 900~1900 rpm for 50Hz (1080~2280 rpm for 60Hz). The control system has built in flexibility regarding energy optimisation, low noise during operation and reduction in loads on gearbox and other components.

1.2 Type approval

The design assessment of the G87–2.0 MW wind turbine is currently being carried out according to the IEC 61400 – 1, Ed. 2, Standard as Class II_A (67m and 78m).

1.3 Climatic conditions

The wind turbine is designed for ambient temperatures ranging from –20º C to +30º C. Special precautions must be taken outside these temperatures (see section 1.5 general reservations).

The wind turbines should be placed in wind farms with a distance of at least 5 rotor diameters (435m) between each other measured along the predominant wind direction. If wind turbines are placed along a row, perpendicularly to the predominant wind direction, the distance between them should be of at least 3 rotor diameters (261m).

The relative humidity can be 100% (10% of time maximum). Corrosion protection for corrosion class C4 or C5-M (outside) and C3 (inside) are provided according to ISO 12944-2.

1.4 Grid connection

The wind turbines must be connected to medium-voltage grid at 10~33 kV. The standard wind turbines is connected to a 20 kV grid, other voltage levels inside the indicated range can be developed when asked by the customer. The maximum voltage of the equipment is 36 kV (Um). The MV-cable connection is made in the bottom of the tower.

The transformer in the turbine must be adjusted to the grid voltage. When ordering GAMESA EÓLICA S.A. will need precise information about grid voltage, as to chooce the transformer's nominal voltage as well as the type of winding connection. GAMESA EÓLICA, S.A. offers the switch gear as an option.

The wind-turbine may generate reactive energy (see section 3.14). Nevertheless, in some occasions, the wind-turbine will limit the reactive power so as to preserve its operation.

The voltage of the medium voltage grid shall be within the range ± 5%. Variations within +1/-3 Hz (for 50 and 60Hz) are acceptable. Intermittent or rapid grid frequency fluctuations may cause serious damage to the turbine.

Grid dropouts must, as an average over the entire lifetime of the wind-turbine, only take place once a week.

A ground connection of maximum 10Ω must be present.

The earthing system must be accommodated to local soil conditions. The resistance to neutral earth must be according to the requirements of the local authorities.

1.5 General reservations

Regarding heavy icing up, interruptions in operation may be expected. In certain combinations of high wind speeds, high temperature, low air temperature, low air density and/or low voltage, power derating may happen to ensure that the thermal conditions of the main components such as gearbox, generator, transformer, power cables, etc, are kept within limits.

It is generally recommended that the grid voltage is as close to nominal as possible. In case of grid dropout and very low temperatures, a certain time for heating must be expected before the wind turbine can start to operate.

If the terrain within a 100m radius of the turbine has a slope of more than 10º, particular considerations may be necessary.

If the wind-turbine is placed in more that 1000 m above the sea level, a higher temperature rise than usual might occur in the generator, transformer and other electrical components. In this case a periodic reduction of rated power might occur, even if the ambient temperature is within the specified limits. Furthermore, also at sites in more than 1000m above sea level, there will be an increased risk of icing-up.

Due to continuous updating of our products, GAMESA EOLICA, S.A reserves the right to change these specifications.

2. Wind-turbine elements

Figure 1 shows the location of the different elements in the nacelle of the G87 – 2.0 MW wind-turbine.

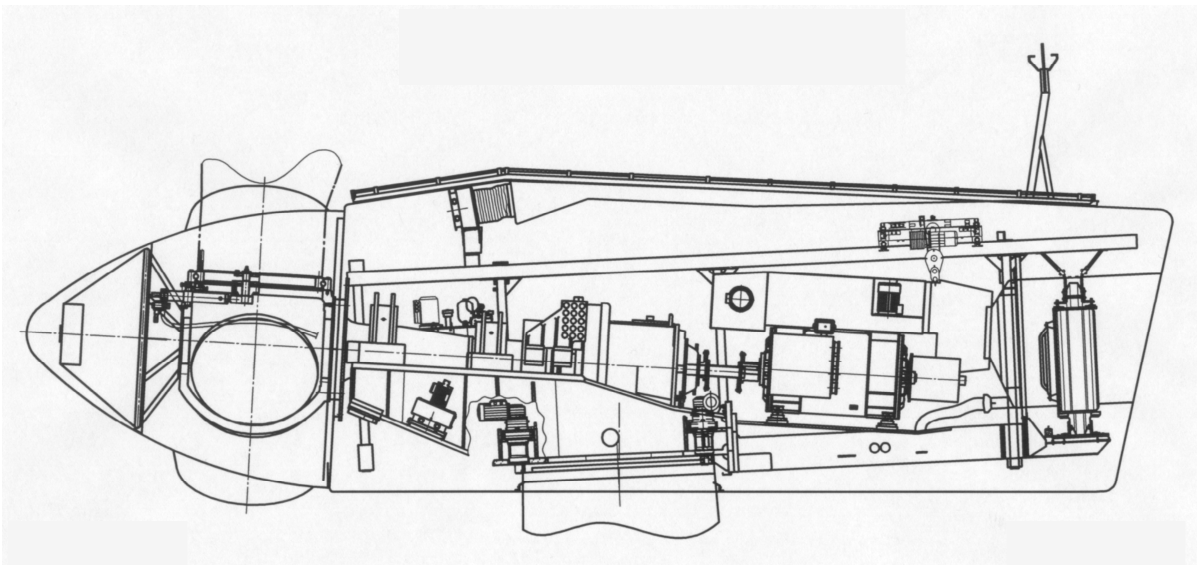

Figure 1 Side section of G87-2.0 MW rotor and nacelle

2.1 Rotor

2.1.1 General

The rotor of G87-2.0 MW consists of three blades attached to a cast iron hub through the blade bearings. The blade coning is 2º so that, the blade tip is kept away from the tower.

2.1.2 Blades

The blades are 42,5m span and a nominal weight of 6200kg. Each blade is fitted with a anti-lightning system that receive lightning discharges by a receptor at the tip, and four more along the blade. The discharge is conducted via a copper cable through the blade to the hub.

The distance between the blade root and the centre of the hub is 1m and, as a result, the diameter of the rotor is 87m.

The blades are made of carbon fiber and glass fiber reinforced epoxy. Their manufacture is based on the pre-preg moulding technology. The manufacturing method is automated by the combination of tape Placement and Tape Winding techniques. This assures that the required mechanical properties are obtained each time the process is repeated and improves the quality in relation to others technologies.

Each blade consists of two shells –made separately-, bonded to a supporting internal spar. The role of this spar is to provide structural resistance to the whole system, bear the own blade loads and transmit the stresses to the hub. On the other hand, the shells have no structural mission but possess the adequate aero-dynamical shape to convert the kinetic energy of the wind into drive torque to generate electricity.

The internal spar is essentially a closed beam of tubular cross-section and its geometry is adapted to the aero-dynamic profile of the blade at each station. The carbon fiber is located in this spar. That means a higher stiffness with a less weight compared with glass fiber blades. The glass fiber blades are dimensioned by maximum deflection; in long blades this would mean an important increase in weight. The carbon fiber introduction let the blades be dimensioned by stress, optimizing the quantity of material. This fact, together with the important stiffness/weight relation compared to the glass fiber, reduces considerably the final weight of the blade and, consecuently, the loads of the rest of wind turbine components.

The carbon and glass fiber combination is an agreement between structural stiffness and cost. If the blade was all in carbon fiber, its cost would be very high. The hybrid blade design means the use of the most advanced technologies in the sector, not only in design but also in manufacture, with the result of an optimum quality/price relation blade.

The outer part (shells) is a sandwich-like construction formed by a PVC core and glass fibre-*epoxy* laminates.

The attachment of the blade to the blade bearing is bolted. This is attained by means of 90 steel threaded inserts embedded in the laminate of the blade root.

2.1.3 Hub

The hub is spherical and manufactured in nodular cast iron. It is directly mounted on the main shaft and has a frontal opening for internal inspections.

2.1.4 Nose cone

The hub and the blade bearings are entirely enclosed and protected from the outside environmental conditions by the nose cone. It is bolted on the front of the hub and supported by a welded steel tube structure.

2.1.5 Blade bearings

The blade bearings fasten the blade with a rotating connection to the hub. The bearing is a double row 4-point contact ball bearing with seals. It has smooth holes in the outer ring to connect to the hub and in the inner ring to connect to the blade.

2.2 Pitch system

The pitch system is working all the times of operation of the wind turbine: (i) When the wind speed is below the rated one the pitch angle is chosen so the electrical power output is maximised for each wind speed; (ii) When the wind speed is above the rated one the pitch angle is adjusted to yield the rated power.

The pitch movement of the blade is a rotation around its longitudinal axis. This movement in G87-2.0 MW wind-turbine is attained by an hydraulic system, which set the three blades at the same pitch angle every time by means of an independent cylinder for each blade.

2.3 Main shaft

The main shaft transmits the drive torque from the rotor to the gearbox. The shaft is joined to the hub through a bolted flange and is supported by two bearings in cast main bearing houses. All loads, except the driving torque, are transmitted to the main frame through these supports. The main shaft is fixed to the low speed hollow shaft of the gearbox by an hydraulic shrink disc.

The main shaft is manufactured in forged alloy steel. In the centerhole of the hollow shaft there is room for the hoses for hydraulic oil and cables for pitch control system.

2.4 Main frame

The machine main frame has been designed to result in a simple and robust foundation suitable for the nacelle components and machinery. It transmits the loads from these elements to the tower through the yaw bearing system.

The nacelle main frame is divided in two parts:

(i) The front foundation is a cast piece where the supports of the main shaft and the yaw ring are fixed.
(ii) The rear frame is composed by two main beams joined both at their rear and front ends. This part has been designed as to support the generator (right), controller (left) and the transformer. Between them, the nacelle floor allows both repair and maintenance tasks to be done.

2.5 Nacelle cover

The nacelle housing is the cover for the protection of the mechanical components from the actions of the environment. This cover is manufactured in glass fibre reinforced polyester. Sufficient standing and working area is provided in the inner of the nacelle for service and maintenance work.

A hatch at the front of the cabin gives access to the inside of the nose cone and the hub. A hatch in the ground of the rear part of the nacelle cover can be opened to operate the service crane. A skylight hatch provides diurnal lighting and additional ventilation and enables easy access to the nacelle roof where the wind sensors and the lightning rods are placed.

High-speed and low-speed rotating parts are conveniently covered by protective screens providing adequate safety for maintenance personnel.

2.6 Wind measurement

Outside the nacelle, in the rear part, two vertical mast support the ultra-sonic anemometers for measuring the wind speed and direction.

2.7 Control system

The controller monitors and controls all functions in the G87 wind-turbine to ensure that its performance is optimal at any wind speed. It continuously scans the signals from the sensors in the wind turbine so that as soon as an error is detected, the appropriate handling takes place. The controller will stop the turbine if the detected error requires so.

There is a touch screen where operational data are displayed and which let the interction between user and wind turbine. The controller is designed as to allow remote monitoring and control in case these features are required. It is also supervised by the system watchdog so that, its correct operation is permanently guaranteed.

2.7.1 Layout of the controller

The control system hardware is placed in three parts:

1. "Nacelle" controller, located at the nacelle.
2. "Ground" controller with a touch screen, located at the bottom of the tower.
3. "Hub" controller, located at the rotating element of the wind-turbine (inside the hub).

The "nacelle" controller is divided into three parts further:

1. Control section: dealing with tasks of the nacelle, i. e. wind monitoring, pitch angle change, orientation, inside temperature control.
2. Frequency converter: dealing with the power control, generator-grid connection/disconnection management.
3. Bars and protection section: dealing with the power output yield with the necessary electrical protections.

2.7.2 Control touch terminal

When an operator wants to look at operational data from the turbine, or to start or stop the turbine, he can use the operating panel in the "ground" controller or connect a service panel to the "nacelle" controller. **Figure 2** shows different operating panel modes.

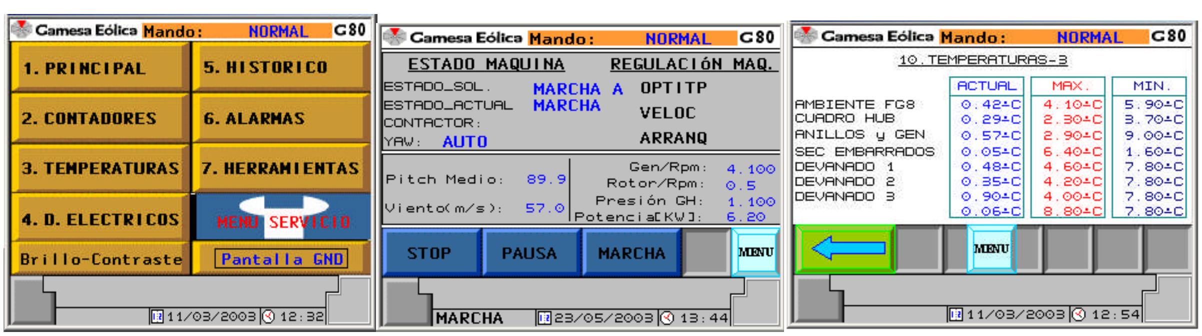

Figure 2. Different operating panel modes

2.7.3 Wind-turbine control

The rotational speed and the pitch angle of the wind-turbine are modified at every instant depending on the existing wind-speed. The control system chooses the adequate values of these variables.

Depending on the wind-speed 4 stages can be established:

1. *Low wind*, with the generator disconnected from the grid.
2. *Medium wind*, with the generator connected to the grid, but rated power is not accomplished.
3. *High wind*, the turbine produces rated power.
4. *Very high wind (stop wind)*, the generator is disconnected and the wind-turbine stopped.

- *Low wind*

  When the wind-speed is below, but close to, the start-wind-speed, the pitch angle will be approximately set equal to 45 degrees. This situation will give a sufficiently high start moment to the rotor.

  As the wind-speed increases the rotational speed -rotor and generator- also increases, and the pitch angle is shifted down to small angles by the controller until the conditions for generator connection are achieved.

- *Medium wind*

  For wind speeds above the start-wind-speed and below the rated-wind-speed the control system works out the most suitable rotor speed -within a certain range of available operating speeds- and pitch angle so that the electrical power yield is maximum for each wind speed.

- *High wind*

  When the wind-speed exceeds the rated wind speed, the wind kinetic energy is sufficient for the turbine to produce rated power, and the pitch angle is increased to regulate the power to its rated value.

- *Very high wind*

  If the wind-speed is greater than the stop value the generator is disconnected and the control system pitches the blades to full feathered position (~90º). Then, the system will wait until the wind-speed has decreased below the re-start wind-speed to re-start the power generation.

2.8 Communication of transformer, control system and medium voltage switch gear

2.8.1 Generator rotor supply

The power supply of the rotor of the generator is performed by means of an 480V output of the main transformer.

2.8.2 Generator cables characteristics

Stator: The generator stator and the power control board located in the nacelle are connected by means of DN-K 0.6/1kV 3x240 mm^2 cables which are designed according to the standard UNE 21150. 4 cables (in parallel) are used to supply the stator.

Rotor: DN-K 0.6/1kV 3x70 mm^2 cables are used.

The power control board and the transformer are connected by means of DN-K 0.6/1kV 1 x 240 mm^2 cables. 4 cables in parallel are used for the stator and 1 for the rotor.

2.8.3 Optical fibre

The optical fibre used for communications inside the turbine has a diameter of 200~230 μm, 4 wires per cable. This fibre is protected against humidity and rodents action.

This fibre is used for the communication between the different processors or between these processors and the user that log in through an operating terminal.

The remote control uses fibre of diameter 62,5~125 μm to communicate different wind-turbines. This fibre is also protected against humidity and rodents action.

3. Design parameters

3.1 Wind conditions

The wind climate for a given site is normally specified by a Weibull distribution. The Weibull distribution is described by the scale factor A and the shape factor K. The A factor is proportional to the mean wind speed and the K factor defines the shape of the Weibull distribution for different wind speeds. Turbulence is the factor, which describes short-term wind variation/fluctuations.

The design conditions of G87-2.0 MW are given below:

Table 4 Design parameters of G87 – 2.0 MW wind-turbine.

Concept	Value	Units	Comments
Class IEC	II_A		IEC 61400-1 Ed. 2
Annual mean wind speed	8,5	m/s	Refered to hub height
Weibull* shape parameter, *k	2		
Turbulence intensity at 15 m/s, I_{15}	18		
Reference wind 10 min. averaged	42,5	m/s	50 years recurrence time
Reference wind 3 sec. averaged	59,5	m/s	50 years recurrence time
Stop / restart wind speed	25 / 20	m/s	-

The power curve (calculated for a turbulence of 10 %) together with the C_p and C_t curves and the annual production of G87 – 2.0 MW wind-turbine are included in the **FT002404** document.

3.2 Wind condition assessment

The turbines can be placed under various climatic conditions: where the air density, the turbulence intensity, the mean wind speed and the shape factor k are the parameters to be considered. If the turbulence intensity is high the turbine loading increases and the turbine lifetime decreases. On the contrary, the loading will be reduced and the lifetime extended if the mean wind speed or the turbulence intensity, or both, are low. Therefore, the wind-turbines can be placed on sites with high turbulence intensity if the mean wind speed is appropriately low. The climatic conditions have to be examined if the prescribed is exceeded

The characteristic value of hub-height turbulence intensity, I_{15}, at a min. average wind speed of 15m/s is calculated by adding the measured standard deviation of the turbulence intensity to the measured or estimated mean value.

For complex terrain, the wind conditions shall be assessed from measurements made at the site. In addition, consideration shall be given to the effect of topography on the wind speed, wind profile, turbulence intensity and flow inclination at each turbine location.

4. Technical specifications

Figures 3 and **4** show the main dimensions of the G87–2.0 MW nacelle-rotor conjunction. Detail of the internal distribution of the nacelle can be observed in **Figure 1**.

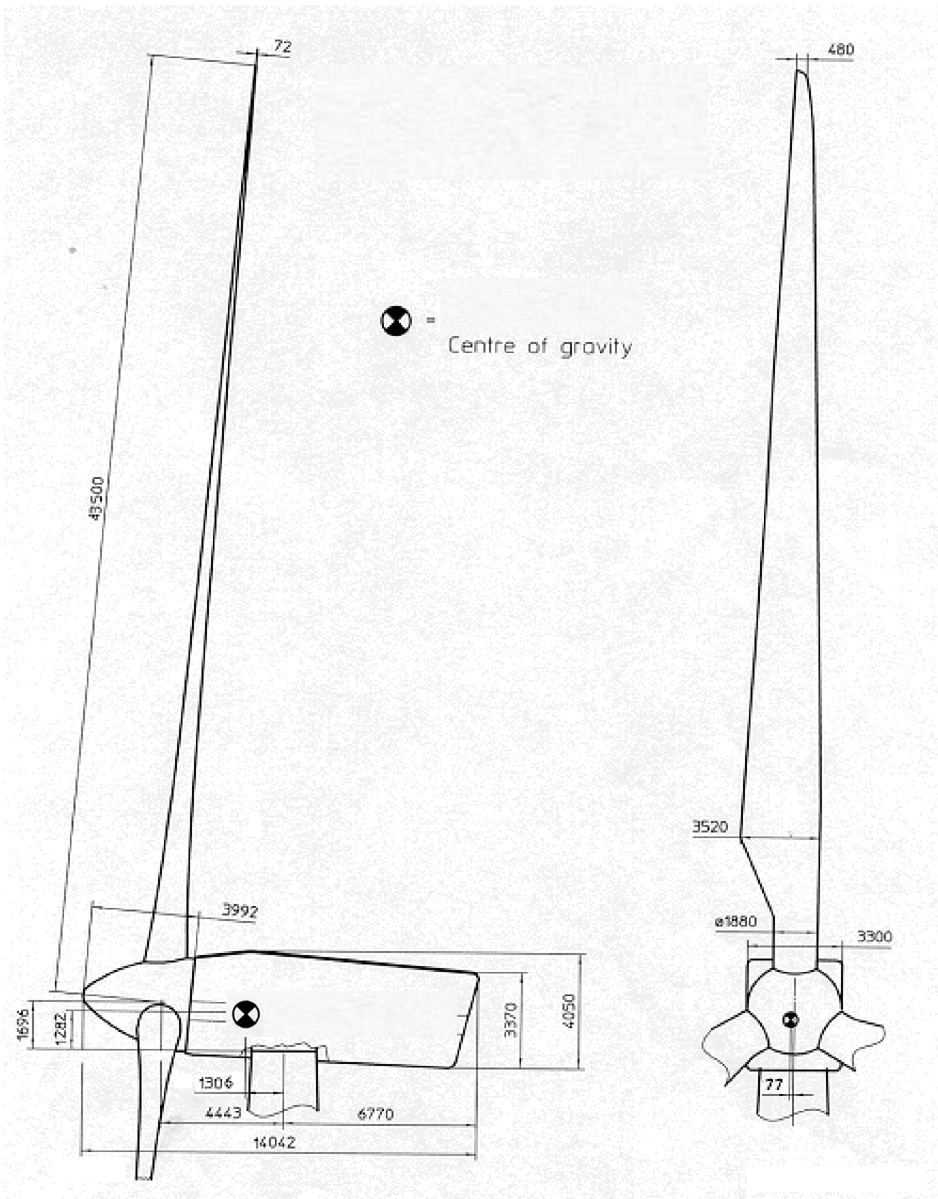

Figure 3 Main dimensions of G87-2.0 MW wind-turbine

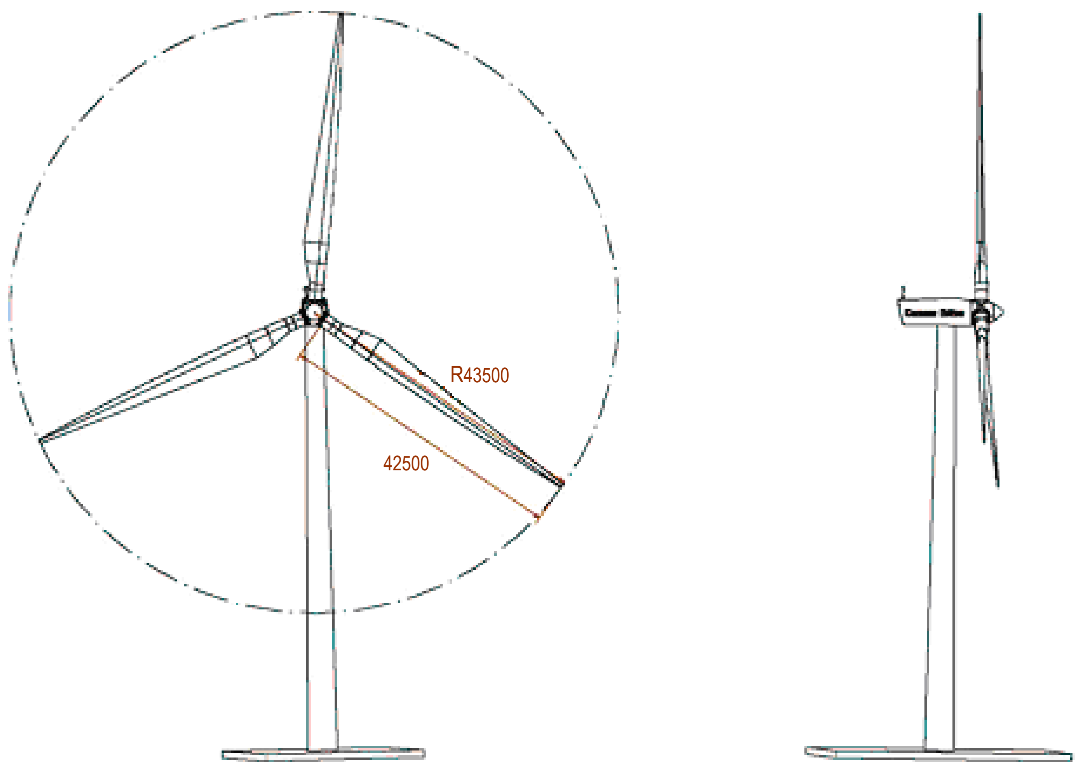

Figure 4 Main dimensions of G87-2.0 MW rotor

The technical specifications of the different components of the G87–2.0 MW wind-turbine are listed below:

4.1 Nose cone

Dimensions	Tip-base distance: 4237 mm Ø max. 3957 mm; Ø base 3300 mm
Material	Glass fibre and polyester resin
Weight	310 kg

4.2 Rotor

Diameter	87 m
Swept Area	5944,68 m^2
Rotational Speed Operation Interval	9.0 : 19.0 rpm
Sense of Rotation	Clockwise (front view)
Rotor Orientation	Upwind

Tilt angle	6º
Blade coning	2º
Number of blades	3
Aero-dynamic brake	Full feathering

4.3 Blades

Principle	Shells bonded to supporting beam
Material	Carbon and glass fibre reinforced epoxy
Blade connection	Steel root inserts
Airfoils	DU-WX + FFA – W3
Length	42,5 m
Chord (root/ tip)	3,357m (at R=8,0m) / 0,013m (at R=43,5m)
Max. Twist	15,74º
Weight	Approx. 6200 kg / piece

4.4 Blade bearing

Type	4-point ball bearing, double row.

4.5 Nacelle cover

Dimensions	10050 x 4050 x 3300 mm^3
Material	Glass fibre and polyester resin
Weight	2000 kg

4.6 Rotor hub

Type	Spherical
Material	Nodular Cast Iron
Material specifications	EN-GJS-400-18U-LT per EN 1563

4.7 Main shaft

Type	Forged shaft
Material	Quenched and tempered steel
Material specification	42CrMo4 EN10083

4.8 Main shaft support

Type	Cast
Material	Nodular Cast Iron
Material specification	EN-GJS-400-18U-LT per EN 1563

4.9 Main shaft bearing

Type	Spherical Roller Bearings

4.10 Front main frame

Material	Nodular Cast Iron
Material specification	EN-GJS-400-18U-LT per EN 1563

4.11 Yaw system

Type	Plain bearing system with built-in active and passive friction
Materials	
Yaw ring	Forged. 34CrNiMo 6 / 42CrMo4 EN10083
Plain bearing	ERTALYTE TX
Yawing speed	< 0.5º/s.
Yaw brake	Hydraulic active

4.12 Yaw gears

Type	3 planetary stages
	1 worm gear non – locking stage (maximum ratio 1:10)
Motor	2,2 kW, 6 pole asynchronous motor with brake

4.13 Tower

Type	Trunk-conical Tubular
Material	Non-alloy structural steel
Material specification	

Shells	S235 JO / S235 JRG2 / S275J2G3 / S355J2G3	
Flanges	S355 NL	
Surface treatment	Painted	
Corrosion class, outside / inside	C5-M (ISO 12944-2) / C3 (ISO 12944-2)	
Top diameter	2,3 m (all heights)	
Bottom diameter	4,0 m (all heights)	
Hub height		
Tower IEC (67 m), divided in 3 parts		67 m
Tower IEC (78 m), divided in 4 parts		78 m

Characteristics of the IEC IIA tower sections				
	Length [mm]	**Outer Ø at Bottom [mm]**	**Outer Ø at Top [mm]**	**Weight [kg]**
Tower IEC IIA 67 m				
Bottom	16665	4034	3490	43000
Intermediate	23822	3490	2780	55400
Top	24367	2780	2314	53100
Tower IEC IIA 78 m				
Bottom	11100	4036	3810	45500
Intermediate 1	16980	3810	3494	55200
Intermediate 2	23822	3494	2780	55500
Top	24367	2780	2314	42600

(*) The exact hub height includes 0,7m (distance from the foundation section to ground level) and 1,7m (distance from top flange to hub).

4.14 Gearbox

Type	1 planetary stage / 2 helical stages
Ratio	1 : 100,5 (50Hz) / 1 : 120,5 (60Hz)
Cooling system	Oil pump with oil cooler; Aux. pump
Oil heater power	2,2 kW
Oil filter	3 µm / 10 µm
Dimensions (approx.)	2 x 2,2 x 2,2 m^3
Weight (approx.)	16500 kg

4.15 Couplings

Main shaft – gearbox	Shrink Disc Conical
Gearbox – generator	Flexible joint

4.16 Generator with control system

Typo	Doubly fed machine with wound rotor and slip-rings
Rated power	2000 kW (stator + rotor)
Voltage	690 Vac
Frequency	50Hz / 60Hz
Number of poles	4
Class of protection	IP54
Rated speed	1680 rpm (50Hz) / 2016 rpm (60Hz)
Nominal current	
Stator	1500 A @ 690 V
Rotor	260 A @ 480 V
Default power factor	1.0
Power factor range (*)	0.98_{CAP} – 0.96_{IND} (option)
	Ver sección 1.5

4.17 Parking brake

Type	Disc brake
Diameter	600 mm
Material	SJV300

4.18 Hydraulic unit

Pump capacity	44 l/min
Maximum pressure	200 bar
Brake pressure	19,5 bar
Oil quantity	160 l
Motor	18.5 kW
Yaw brake pressure	180 bar

4.19 Wind sensors

Type	2D sonic anemometer with simultaneous measurement of wind speed and direction.
Number	2

4.20 Control unit

Power supply		
Frequency	50 Hz / 60Hz	
Voltage	3 x 690 Vac + 3 x 480 Vac	
Lockable circuit breaker	1500 A (stator); 260 A (rotor)	
Illumination	1 x 10 A, 230 Vac/ (1 x 10 A, 110 Vca)	
Computer	Sisteam A	
Communication	CAN	
Program memory	EPROM (flash)	
Programming language	ST (IEC-1131)	
Configuration	Modules to a front rack	
Operation	Touch terminal	
Display	Touch terminal, 320 x 240 pixels, 5,7 inch	
Supervision / control		
	Active power	Ambient (air temperature)
	Reactive power	Rotation
	Yawing	Generator
	Hydraulics	Pitch system
	Grid	Remote monitoring
Information		
	Operating data	Operation log
	Production	Alarm log
Commands		
	Run /pause	
	Start / Stop. Manual yaw	
	Maintenance tests	
Remote supervision		
	Possibility of connection of serial communication	

Nacelle, hub and ground controller data		
Protection level		
	Nacelle	IP-43
	Hub	IP-54
	Ground	IP-54
Dimensions		
	Nacelle	4000 x 2200 x 500 mm^3
	Hub	800 x 800 x 400 mm^3
	Ground	800 x 1600 x 400 mm^3
Type of enclosure	Steel. Thickness 3 mm (cabinet, pedestal); 1,5 mm (door)	
Method of protection of persons	UNE 60439-1; UNE 60204	

4.21 Medium voltage switch gear

The switch gear of the windturbine is included in the supply of Gamesa Eólica, S. A. as an option. This gear has to be chosen according to the electrical characteristics of the grid connection. Below, characteristics of one type of gear are shown. This gear corresponds to the G87-2.0 MW standard for a grid connection of 20 kV. For other voltage levels, it is necessary to contact Gamesa Eólica, S. A.

Type	Armoured isolated SF6
Service	Continuous
Installation	Inside
Number of phases	3
Busbar number	1
Assigned nominal voltage	24 kV
Service voltage	20 kV
Nominal frequency	50 Hz / 60Hz
Nom. Intensity, Protection function (P)	200 A
Nom. Intensity, Grid connection function (L)	400 A
Insulation level	
Ground, between poles and between terminals	50 kV (industrial freq.) / 125 kV (peak freq.)
Short-circuit intensity	
Permissible of short duration (1 s)	16 kA
Nominal pulse	40 kA
Resistance	
Intensity	16 kA-0.5 s (UNE 20099-CEI 298)
Voltage	24 kV
Dimensions (approx. for larger unit) (*) (**)	1200 x 800 x 2090 (height) mm^3
Weight (approx. for larger unit) (*) (**)	415 kg

(*) Biggest gear
(**) The switch gear depends on the characteristics of the connection port of the generator. The indicated data correspond to one of the possible situations.

4.22 Transformer

Type	3 phase, dry-encapsulated
Transformation relation	20 kV / 480 V / 690 V
Nominal power	2100 kVA
Frequency	50 Hz / 60Hz
Connection group	Dyn11
Insulation class	F
Insulation level (kV)	24 kV.
Weight (approx.)	< 5000 kg

4.23 Weights

Towers IEC II_A	**67 m**	**78 m**
Tower (*)	151,5 t	198,8 t
Góndola	71,8 t	71,8 t
Nacelle	37,1 t	37,1 t
Total	**260,5 t**	**307,8 t**

(*) It does not include the switch gear and the ground controller.