ecotècnia

your best partnership

2007

Technical characteristics

25th
1981-2006

ECOTÈCNIA, s.coop.c.l.

ECOTÈCNIA, s.coop.c.l.
Roc Boronat, 78 - 08005 BARCELONA (Spain)
Tel. +34 932 257 600
Fax +34 932 210 939
ecotecnia@ecotecnia.com

ECOTÈCNIA France, s.a.s.
281 Route d'Espagne - 31100 TOULOUSE (France)
Tel. +33 (0) 534 630 360
Fax +33 (0) 534 630 361
ecotecnia@ecotecnia-france.com

ECOTÈCNIA Italia s.r.l.
Via di Vigna Murata, 40 - 00143 ROME (Italy)
Tel. +39 06 54832085
Fax +39 06 54834000
ecotecnia@ecotecnia-italia.com

February, 2007

MONDRAGON
CORPORACION COOPERATIVA

Principal characteristics

The ECOTÈCNIA 80 wind turbine of 1,670 kW nominal power has been designed following the Class III specifications of standard IEC61400-1, suitable for sites with a mean annual wind speed of up to 7.5 m/s and an extreme gust speed with a 50-year repetition frequency of 52.5 m/s.

The wind turbine has a special mechanical configuration based on supporting the rotor directly on the frame, separating the tasks of supporting it from those of torque transmission. The drive train has a carefully-studied design that includes controlled flexibility and torque control in any situation. This, combined with variable-speed operation, permits a reduction of the number of cycles and extreme loads to which the drive train is subjected.

This mechanical design concept, which is ECOTÈCNIA's own, has amply demonstrated its efficiency in the company's commercial wind turbines of lower power (640, 750 and 1300 kW), of which over 900 units have been installed to date.

- **ECOTÈCNIA mechanical design concept**
  - Rotor supported directly by the frame
  - Flexible drive train. Floating shaft
  - Transmission of loads directly to the structure
  - Yaw system by means of gliding pads

The ECOTÈCNIA 80 wind turbine, which has a power density of 3.01 m^2/kW, has been designed for optimal exploitation of Class III sites by means of incorporating active damping mechanisms. A highly efficient control system incorporating control mechanisms in function of the structure has made it possible to attain a diameter of 80 m.

- **Innovative features**
  - Modular conception of the wind turbine
  - Independent pitch control in each blade
  - Decentralized control system
  - Built-in predictive maintenance
  - Active damping systems

- **Optimization of the characteristics of the wind turbine**

The incorporation of these systems into ECOTÈCNIA's traditional design concept has made it possible to achieve optimal performances of the wind turbine and the windfarm, which can be summarized as follows:
  - Greater cost-effectiveness of the wind turbine
  - Reliability
  - Integrability into the electrical grid
  - Environmental compatibility

ECOTÈCNIA mechanical design concept

ECOTÈCNIA began developing its first wind turbine in 1981. As a result of these 25-plus years of experience, it has evolved an advanced concept of wind turbine in which the gearbox, much more protected, is subjected to much lower loads than in conventional configurations, thus lengthening its working life:

- The rotor, resting directly on the frame, is not supported by the gearbox, which means that this component is not subjected to the great asymmetry of loads caused on the rotor by the wind.

- The fixing of the rotor means that the loads are deflected to the tower and only the useful loads are transmitted to the drive train.

- The length of the shaft gives the drive train considerable elasticity, thus preventing load peaks on the gearbox.

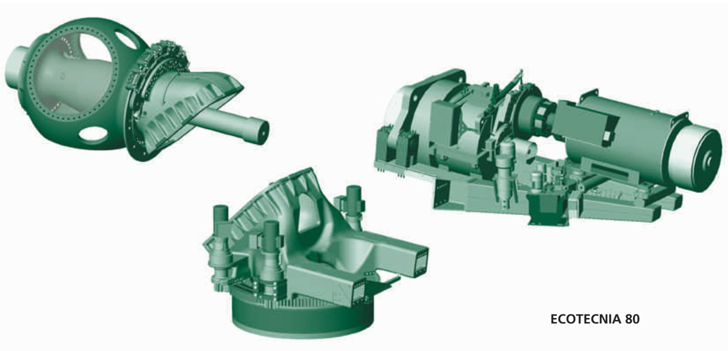
The position of the gearbox, separated from the support structure, prevents it from being subjected to loads deriving from the behavior of the latter, such as deformations or displacements of large masses.

Innovative features

• Modular conception of the wind turbine

The wind turbine is conceived in modular form. The nacelle is made up of three modules formed by the following components:

Module 1: Rotor, bearings and shaft
Module 2: Mainframe, yaw system and housing support
Module 3: Drive train



These modules include both the mechanical components and the control systems, thus allowing independent verification of their integrity and operation. Their manufacturing process is therefore also independent, and they are interchangeable.

These modules have reduced weight and compact external dimensions, thus facilitating transport operations. In addition, the modules can be assembled at the top of the tower, thus reducing the requirements for assembly cranes and auxiliary elements.

The modularity of the wind turbine offers the following advantages:

- Less need for civil engineering infrastructure: access to the site with the nacelle is made easier by having to transport only components weighing less than 30 Tn.
- Ease of transport: the modules have weights and dimensions which enable them to adapt to standard transport procedures (containerization).
- Less requirement of cranes: due to the reduced weight of the modules, the wind turbine can be hoisted with cranes of the same capacity as those currently used for machines of less than 1 MW power. This also means lower civil infrastructure requirements at the siting point.
- Better exploitation of complex terrains due to ease of installation.

• Independent pitch control in each blade

The incorporation of independent pitch control in each blade represents a significant advance over the traditional wind turbine in terms of safety and regulation. The principle is based on having three independent electrical pitch control systems, one for each blade.

The functions of the pitch control are to carry out the commands of the central control system, with which it is communicated by means of a digital bus. The redundancy due to the existence of independent systems in the three blades ensures greater safety.

Advantages of incorporating the pitch control system:

- Control of the rotor speed within the regulation margin, maintaining the power constant in the grid.
- Reduction of extreme loads in the structure, enabling operation in strong winds with the blades in closed position without the risk of gusts of wind causing extreme values of operational loads. In the "machine stopped" situation or storms, the loads in the support structure and foundations are lower.
- Elimination of the mechanical brake without loss of safety. The independent activation ensures the braking of the wind turbine in any circumstance. A fault in one of the pitch control systems is not critical for the structural safety of the wind turbine.

- Start-up in low winds, by providing significant torque values at low turning speeds.

- Better use of blades when dirty, by allowing the position of optimal aerodynamic performance to be sought.

- Active damping of the structure in the direction parallel to the rotor shaft. The use of acceleration signals of the nacelle and their inclusion in the pitch control loop allows the oscillations of the structure (nacelle-tower) to be actively damped, thus reducing fatigue loads.

- Special power reduction for high wind speeds by rotational speed and torque reduction. This strategy is very rentable for a wind class III turbine because it reduces efficiatly the loads with very few energy loss.

- **Decentralized control system**

The control system incorporates a large proportion of the innovations presented by the wind turbine. It consists of a decentralized system formed by interconnected elements which perform specialized functions, notably:

- Management control system (supervision of the systems of the wind turbine and operation of activating elements and sensors).

- Torque control system (vectorial control of the generator and its synchronization with the grid).

- Blade pass angle control system.

- Status monitoring system. Measurement of vibrations.

- ARGOS windfarm monitoring and control system.

The effective control of the drive train is based on the capacity of injecting electrical energy into the grid in a controlled manner within a wide range of turning speeds. This is based on a fast control system based on DSP and power electronics capable of modeling the electromagnetic processes (vectorial control of the electrical machine) of the interior of the generator in real time. This makes it possible, for example, to feed constant power into the grid free of influence of speed variations in the drive train.

The following advantages are achieved by means of the torque control:

- Increase in energy produced throughout the wind speed range: at low speeds, by improving the aerodynamic performance of the rotor, and at high speeds by permitting efficient control of the power, preventing the external influences of dirt on the blades and changes in density and temperature.

- Improved operational conditions.

- Reduction of peaks and oscillations in the production of energy and reduction of extreme loads in the drive train. Transient-free inter-connection.

- Possibilities of control of the power delivered to the grid.

- Dynamic control of the reactive power, allowing a contribution of regulation to the grid. Improved characteristics for weak grids.

- Active damping of the drive train.

• Lower environmental impact due to reduction of turning speed at low wind speeds.

• Less risk of bird collision thanks to reduced frequency of blade-tip passage, due to reduced turning speed at low wind speeds.

• **Built-in predictive maintenance (Optional)**

The integration into the windfarm control and monitoring systems of status monitoring systems of the wind turbine elements enables predictive maintenance to be carried out in automated or remote mode.

This predictive maintenance is based on monitoring the status and condition of the machinery throughout the lifetime of the units. In general it is based on the measurement of vibrations, allowing the monitoring of their operation on time scales of the order of the lifetime of the complete system.

The integration into the control systems of fast vibration measurements and their direct frequential processing permit the periodical collection of data to establish the evolution of the status and to establish alarms or stoppages requiring an inspection of the wind turbine.

The data analysis is separated into two frequency ranges;

• Low-frequency range (up to 10 Hz), in which the behavior of the structure of the wind turbine is analyzed. In this range the analysis is based on the modes of the wind turbine itself, the aim being a permanent diagnosis of the correct status of the structure of the wind turbine. This range includes also the low-speed rotary elements (rotor).

• High-frequency range (10 to 4000 Hz), in which the rotary elements of the drive train are analyzed. In this range the analysis is based on monitoring the multiple frequencies of the turning speed, and in a variable-speed machine it requires special frequential processing.

Optimization of the characteristics of the wind turbine

The contribution of all of the above elements to the design of the ECOTÈCNIA 80 wind turbine has made it possible to achieve optimal performances of the functional characteristics of the wind turbine and the windfarm, notably in the following aspects:

Greater cost-effectiveness of the wind turbine.
• Optimization of aerodynamic behavior.
• Significant reduction of mean and peak loads in the drive train.
• Reduction of extreme loads.
• Reduction of cyclic loads by incorporating active damping.

Reliability
• Permanent collection of data on the status of rotary components.
• Safer operation due to reduction of load variations in the drive train.

Integrability into the electrical grid
• Control of the power supplied.
• Reduced power variations.
• Smooth, transient-free interconnection, even in winds close to the extreme operational speed.

• Capacity of control of reactive power.
• Increased ratio of mean power to installed power.

Environmental compatibility
• High unit power per wind turbine (1670 kW)
• Better wind harnessing, due to the wind turbine design being optimized for Class III sites.
• Fewer civil infrastructure requirements, for both access tracks and the types of cranes needed for installation.

Table of technical characteristics

• General Description

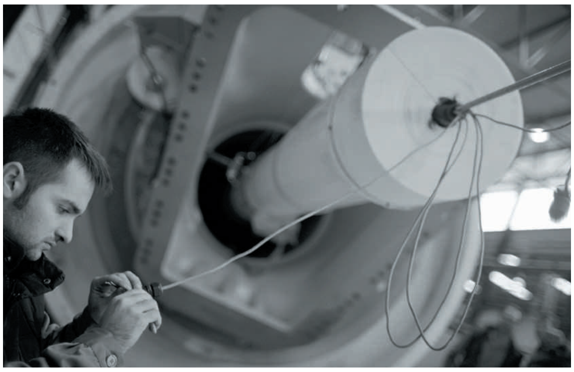
General Characteristics

Wind turbine class as per IEC61400-1	III-A
Nominal power	1670 kW
Rotor diameter	80 m
Rotor yaw	Upwind
Number of blades	3
Standard hub heights	60m, 70 m and 80m
Power control system	Variable-speed with independent pitch control in each blade
Speed range	9.7 r.p.m. - 18.4 r.p.m.
Cut-in and cut-out wind speed (mean 10')	3 m/s and 25 m/s
Range of operating temperatures	-10 ºC – 40 ºC

• Design Specifications

Design Specifications

Wind turbine class as per IEC61400-1	III-A
Mean annual wind speed for which it is suitable	7.5 m/s
Maximum speed (mean 10')	37.5 m/s
Extreme gust speed (3s)	52.5 m/s
Cut-in speed	3 m/s
Cut-out speed	25 m/s
Instant stoppage speed	34 m/s
Turbulence intensity	A
Vertical wind speed throughout the operative life of the wind turbine	8º



- **Main Components and Systems**

Rotor

Rotor position	Upwind
Rotor diameter	80 m
Nominal power	1670 kW
Number of blades	3
Swept area	5.027 m2
Power density	3.01 m2/kW
Range of turning speeds	9,7 - 18.4 r.p.m.
Nominal blade tip speed	77 m/s
Blades manufacturer	LM
Type of blades	LM 37.3

Hub, Shaft and Bearings

Hub material	Nodular cast iron EN-GJS400-18U-LT
Type of main bearings	2 conical roller bearings (front and rear), housed inside the hub
Bearings manufacturer	FAG or SKF or equivalent
Transmission shaft material	F·1252 UNE 36-012-75
Length of the cylindrical shaft	4.17 m
Hub-shaft coupling system	Contraction ring and elastic coupling

Gearbox

Type	Planetary + parallel shafts
Manufacturer	Winergy PEAB 4390.2 or equivalent
Gearing ratio	98.07
Power	1790 kW
Nominal torque	910 kNm
Cooling system	Active by means of radiator with forced ventilation
Lubrication system	Oil, by active lubrication
Shaft-gearbox coupling	Contraction ring
Gearbox-generator coupling	Contraction ring and elastic coupling
Operating temperature	65ºC with ambient temperature 40ºC

Generator

Type	Doubly-fed induction generator
Manufacturer	SIEMENS, WINERGY or equivalent
Nominal power	1,700 kW
Nominal voltage	690 V ±10%
Nominal speed range	1800 r.p.m.
Power-electronic converter	Two-directional 750/400 kVA, IGBT technology
Protection class	IP54
Cos phi range at nominal power	0.95 inductive / capacitive
Cooling system	Air/Air

Tower

Type	Steel tube
Height	60m, 70 m or 80m
Top diameter	2.13 m
Bottom diameter (70 m. tower)	4.25 m
Color	RAL 7035

Control system

Type	Torque and pitch control
Torque control	DSP and power electronics
Control of blade pass angle (pitch control)	Three independent microprocessor controlled systems, one for each blade (electrical pitch control).
Interconnection/communication protocols	Bus Device Net and TCP-IP
Monitoring	ARGOS system

Yaw system

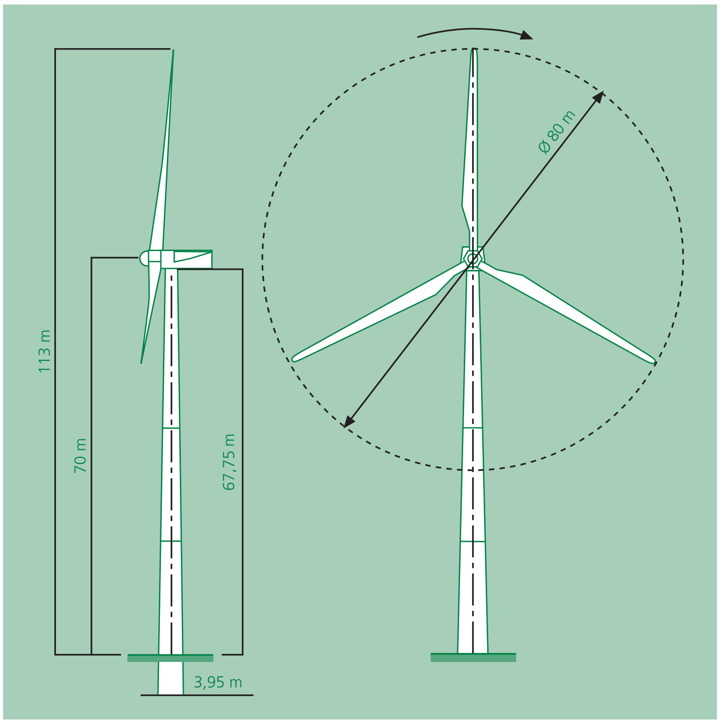
Type	Active
Yaw speed	0.47 °/s
Yaw system	3 polymer gliding pads
Yaw motor	4 electrical motors and planetary-type gears
Activation	At variable frequency and torque control
Manufacturer	Bonfiglioli or equivalent
Yaw brake	2 guide shoes acting as clamps, by means of hydraulic safety system

Braking system

Main brake	Aerodynamic, by means of pitching of the blades
Stop (parking) brake	Disc brake located on the high-speed shaft

Dimensions and Weights

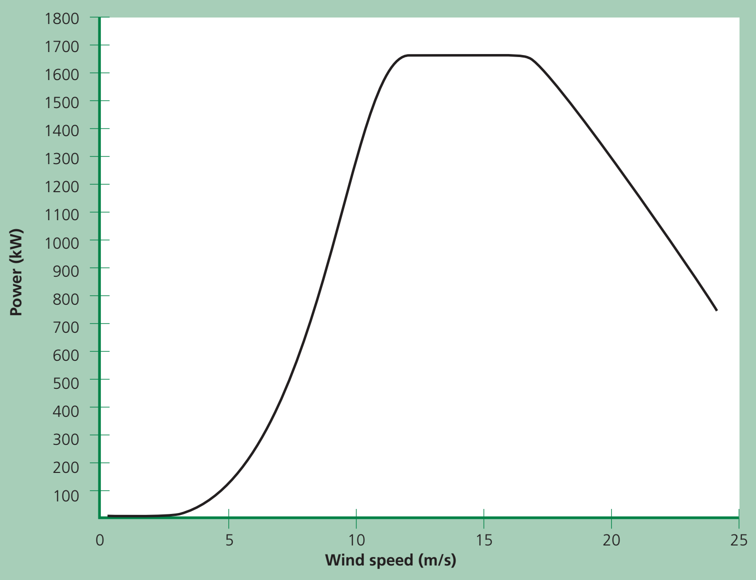
Nacelle (including hub)	67,000 kg
70 m. tower	132,000 kg
Blades (unit)	6,035 kg



Power curve

Density = 1.225 kg/m³, Altitude = 0 m, Temperature = 15ºC

Speed [m/s]	Power [kW]
3,5	31
4,5	96
5,5	196
6,5	344
7,5	546
8,5	809
9,5	1124
10,5	1468
11,5	1619
12,5	1670
13,5	1670
14,5	1670
15,5	1670
16,5	1670
17,5	1529
18,5	1419
19,5	1308
20,5	1198
21,5	1087
22,5	976
23,5	866
24,5	755



ecotècnia