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 ECOTECNIA 74 wind turbine, configured with a rotor diameter of 74 m, has been designed following the Class II specifications of the IEC-1400 standard, suitable for sites with a mean annual wind speed of up to 8.5 m/s and an extreme gust speed with a 50-year repetition frequency of 60 m/s.

The wind turbine has a special mechanical configuration based on supporting the rotor directly by means of the frame, separating its support tasks from those of torque transmission. The drive train has a carefully-studied design which includes controlled flexibility and torque control in any situation. This, together with the variable-speed operation, allows 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 lower-powered commercial wind turbines (640, 750 and 1300 kW), of which over 900 units have been installed to date.

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

The ECOTECNIA 74 wind turbine, which has a power density of 2.57 m^2/kW and incorporates a whole series of innovative elements and systems, has been designed to take optimal advantage of Class II sites.

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

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

The incorporation of these systems into ECOTÈCNIA's traditional design concept makes it possible to achieve optimal performance of the wind turbine and the wind farm, which can be summarized as follows:

- Greater profitability of the wind turbine.
- Reliability.
- Integrability into the electrical grid.
- Environmental compatibility.

ECOTÈCNIA mechanical design concept

ECOTÈCNIA began developing its first wind turbine in the year 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 normal 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, with the result that only the useful loads are transmitted to the train.

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

The positioning 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.

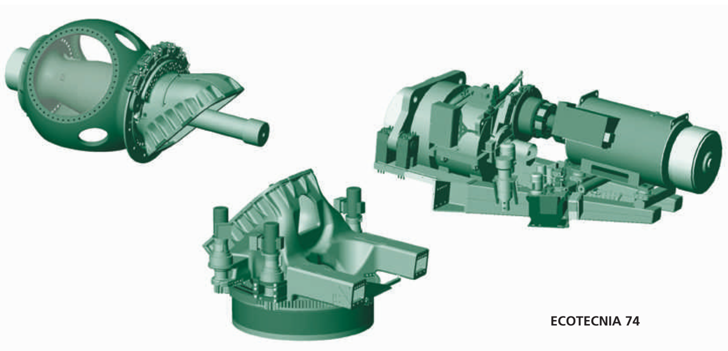
In extreme situations, these loads can cause overloads which were not foreseen in the load simulation and calculation stage.

Innovative features

• Modular conception of the wind turbine

The wind turbine is conceived in modular form. The nacelle is composed of three modules which make up 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 external dimensions, which facilitates transport. In addition, the modules can be assembled on the top of the tower, thus reducing the needs for assembly cranes and auxiliary elements.

The modularity of the wind turbine gives the following advantages:

- Less need for civil engineering infrastructure: the access of the nacelle to the site is facilitated by transporting only components weighing less than 30 Tn.

- Ease of transport: the weight and dimensions of the modules enable them to be incorporated into standard transport procedures (containerization).

- Reduced need for 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 signifies fewer needs of civil infrastructure on site.

- Better use of complex terrains due to the ease of installation.

• Independent pitch control in each blade

The incorporation of independent pitch control in each of the blades 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, since one single blade in a downwind position is capable of maintaining the rotor in a safe situation.

Advantages of the incorporation of 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 the fatigue loads.

• **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 wind farm 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 inject a 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, 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. Interconnection without transients.

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

• Dynamic control of the reactive power, which even permits adding regulation to the grid. Improved grid characteristics in the case of weak grids.

• Lower environmental impact, by reducing the turning speed at low wind speeds.

• Lower risk of bird collision as a result of the reduced pass frequency of the blade tip due to the lower turning speed in low winds.

• Built-in predictive maintenance (Optional)

The integration into the wind farm control and monitoring systems of status monitoring systems of elements of the wind turbine makes it possible to perform the predictive maintenance in automated or remote form.

The predictive maintenance is based on monitoring the status and condition of the machinery throughout the life of the units. In general it is based on the measurement of vibrations, allowing operation to be monitored in time scales of the order of the lifetime of the complete system.

The integration into the control systems of fast measurements of vibrations, and direct frequential treatment of these, permits the periodical collection of data to establish the evolution of the status and also 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 also includes 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 a singular frequential treatment.

Optimization of the characteristics of the wind turbine

The incorporation of all of the above elements into the design of the ECOTECNIA 74 wind turbine has made it possible to achieve optimal performance of the functional characteristics of both the wind turbine and the wind farm, notably in the following aspects:

Greater profitability of the wind turbine
• Optimization of the aerodynamic behavior.
• Significant reduction of mean loads and peaks 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 the rotary components.
• Safer operation due to the reduction of load variations in the drive train.

Integrability into the electrical grid
- Control of the power supplied.
- Reduced power variations.
- Soft interconnection, free of transients, 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 design of the wind turbine being optimized for Class II sites.
- Fewer civil infrastructure requirements, for both access tracks and the models of cranes needed for installation.
- Exceptionally low noise level, consisting mainly of aerodynamic noise. The special design of the tip of the blade and its outer trailing edge minimizes the emission of noise. Variable-speed operation reduces the intensity of noise generated at low wind speeds.

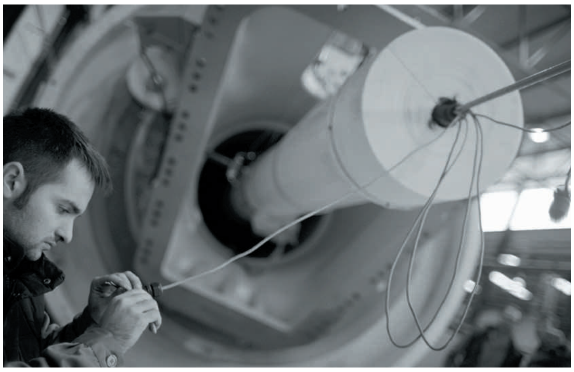
Table of Technical Characteristics

• General description

Wind turbine class as per IEC-1400-1	II - A
Nominal power	1670 kW
Rotor diameter	74 m
Rotor yaw	Windward
Number of blades	3
Standard hub height (tronco-conical tubular tower)	60 m - 70 m - 80 m
Power control system	Variable-speed with independent pitch control in each blade
Speed range	10 r.p.m. - 19 r.p.m.
Cut-in and cut-out wind speed (mean 10’)	3 m/s and 25 m/s
Operational temperature range	-10 °C to + 40 °C

• Design specifications

Wind turbine class as per IEC-1400-1	II
Mean annual wind speed for which it is suitable	8.5 m/s
Max. speed (mean 10’)	42.5 m/s
Extreme gust speed (IEC)	59.5 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 (IEC)	8°



- **Main components and systems**

Rotor

Yaw	Windward
Rotor diameter	74 m
Nominal power	1670 kW
Number of blades	3
Swept area	4301 m^2
Power density	2.57 m2/kW
Range of turning speeds	10 r.p.m. - 19 r.p.m. at nominal power
Blade tip speed	73,6 m/s
Blades manufacturer	LM Glassfiber
Type of blades	LM 34.0

Hub, shaft and bearings

Material of the hub	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 equivalent
Material of the transmission shaft	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 and model	Winergy PEAB 4390.2
Gearing ratio	94.63 (50 Hz)
Mechanical power	1790 kW
Nominal torque	900 kNm
Cooling system	Active, by means of radiator with forced ventilation.
Lubrication system	Oil, by means of active lubrication
Shaft-gearbox coupling	Contraction ring
Gearbox-generator coupling	Contraction ring and elastic coupling
Operating temperature	65° C with ambient temperature 40°

Generator

Type	Double-feed induction generator based on IGBT technology
Manufacturer	ABB, SIEMENS or equivalent
Nominal power	1700 kW
Nominal voltage	690 ±10%
Nominal turning speed	1800 r.p.m.
Power wave inverter	Two-directional 750/400 kVA, IGBT technology
Protection class	IP54
Cos phi range at nominal power	0.95 inductive - 0.95 capacitive
Cooling system	Air/Air

Tower

Type	Tronco-conical tubular steel
Height	60 m / 70 m / 80 m
Top diameter	2.13 m
Bottom diameter (70 m. tower)	4.25 m
Color	RAL 7035

Control System

Type	Control of torque and pass angle
Torque control	DSP and power electronics
Control of the blade pass angle (pitch control)	Three independent systems for each of the blades controlled by microprocessor. (Electrical pitch control)
Interconnection and communication protocols	Bus Device Net and TCP-IP
Monitoring	ARGOS system with remote access

Yaw system

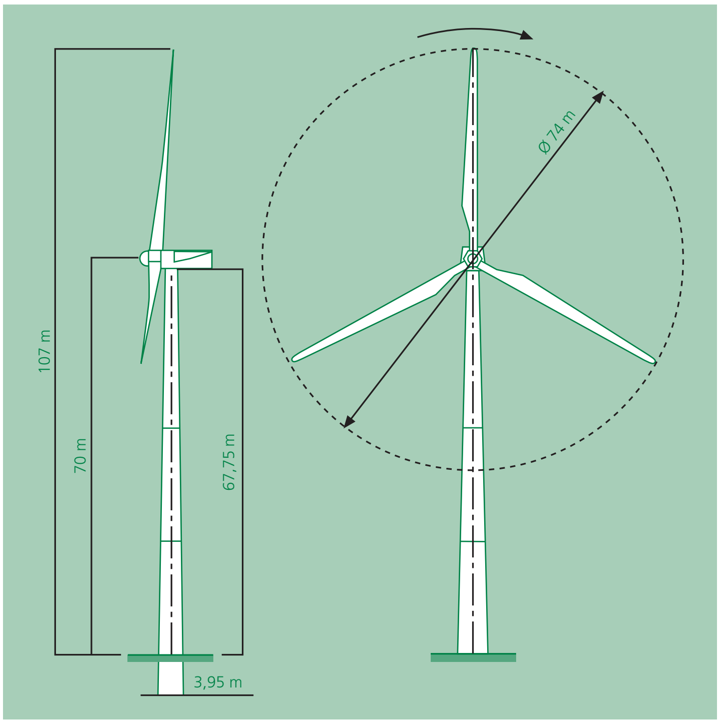
Type	Active
Yaw speed	0.47 º/s
Yaw system	3 polymer shoes
Yaw motor	4 electrical motors and planetary-type gears
Activation	At variable frequency and torque control
Manufacturer	Bonfiglioli or equivalent
Yaw brake	2 guide shoes acting as calipers, by means of hydraulic safety system

Braking system

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

Dimensions and weights

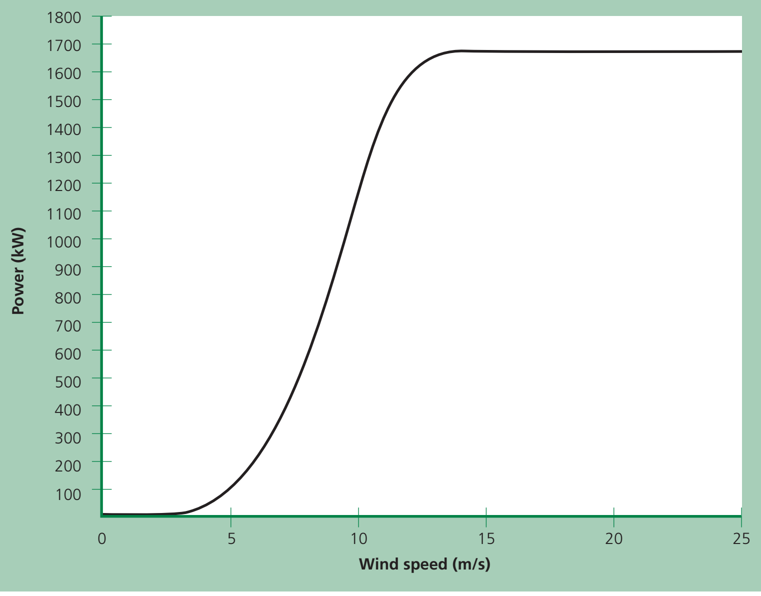
Nacelle (including hub)	67.000 Kg
Tower 70 m.	132.000 Kg
Blades (unit)	5.600 Kg



Power curve

Speed [m/s]	Power [kW]
3	7
4	50
5	118
6	226
7	378
8	580
9	840
10	1138
11	1463
12	1625
13	1670
14	1670
15	1670
16	1670
17	1670
18	1670
19	1670
20	1670
21	1670
22	1670
23	1670
24	1670
25	1670

Density = 1.225 kg/m^3, Height = 0 m, Temperature = 15ºC



ecotècnia